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Abstract

This thesis investigates the energy performance of resorts in Sharm el Sheikh located on the Red Sea coast in Egypt and its impact on environmental sustainability. Studies show that tourism and the building industries are two of the highest energy consumers worldwide where tourism accommodation comes in second place after transportation in its share of energy demand. Meanwhile, there is a steady growth in tourism in Egypt considering its major role in the country's economy. The target set by the Egyptian Ministry of Tourism to increase its share in the world tourism market to 1.2% by 2017 requires naturally an increase in the accommodation capacity which has instigated the extensive development of new areas on the Red Sea coast such as Sharm el Sheikh. This expansive development results in higher demands of energy which poses an increasing burden on the country's economy considering the highly subsidised energy in Egypt. Moreover, the very low costs of energy encourage higher consumption with no attention paid to either energy savings, efficiency measures or to the green house gas emissions.

Egypt lies in a region which enjoys high potential for renewable energy, specifically, solar and wind energies. It is almost located in the centre of the Sunbelt region allowing the use of different kinds of solar technologies for producing not only thermal energy but cooling and power as well. However, renewable energy is not very popular in Egypt, specially, for small to medium applications such as the building sector. There is always the argument that the investment costs are extremely expensive. Therefore, it is the objective of this thesis to evaluate solar resorts versus the conventional design resorts in terms of energy, economic and environmental performances. In order to achieve that, an energy audit was conducted among five stars resorts located in Sharm el Sheikh. Out of the 36 resorts, classified as fives stars, only 39% responded and participated in the energy audit while only 19% provided usable and consistent information. The aim of the audit is to identify the current design practices in addition to the energy and water consumption per guest-night in Sharm el Sheikh. The results show the lack of energy efficiency measures in Sharm el Sheikh resorts and the potential of reducing consumptions in comparison to energy consumptions in Cyprus and Majorca. This information is needed to establish a benchmark and develop the proposed solar resort design.

In order to economically and environmentally evaluate the different design alternatives, the author develops a resort evaluation model based on the concept of environmental life cycle costing. The model is, accordingly, used to evaluate the conventional resort versus the solar resort concept. Several what-if scenarios are performed identifying the critical parameters and their impact on the results of the evaluation model. The results show that under the current conditions, the total capital investment and the life cycle cost are much lower in the conventional resort while the equivalent CO_2 emissions can be immensely reduced adopting the solar resort concept. However, should the energy prices increase as a result of introducing a new energy law, removal of subsidies and/or increase in global energy prices, the life cycle costs of the conventional design increases to the extent that solar resorts are financially attractive in additional to their environmental benefits.

The thesis concludes with the discussion of the results and recommendations for encouraging the use of renewable energy in the hotel sector in Egypt in order to achieve the aspired environmental sustainability.

Keywords: *benchmark, CDM, CO2 emissions, Egypt, energy audit, energy efficiency, energy performance, energy use, environmental sustainability, evaluation model, hotels, renewable energy, resorts, solar resorts, solar architecture, sustainable energy, tourism*

Abstract

Diese Dissertation untersucht die Energieeffizienz von Ferienhotels in Scharm el Scheich an der Küste des Roten Meers in Ägypten und ihren Einfluss auf die Umweltverträglichkeit. Untersuchungen haben gezeigt, dass die Tourismus- und Bauindustrie zu den zwei größten Energieverbrauchern weltweit zählen, wobei das Hotelwesen nach dem Transportsektor den zweithöchsten Energiebedarf auf sich vereinigt. Die Tourismusbranche gehört zu den Schlüsselindustrien der ägyptischen Wirtschaft und kann inzwischen auf ein stetiges Wachstum zurückblicken. Zielvorgabe des ägyptischen Tourismusministeriums ist es, den Anteil am weltweiten Tourismusmarkt bis zum Jahr 2017 auf 1.2% zu vergrößern, was natürlich den Ausbau der Hotelbettenkapazität nötig macht und bereits zu einer umfangreichen Erschließung neuer Urlaubsgebiete am Roten Meer wie etwa Scharm el Scheich geführt hat. Dieser expansive Ausbau führt zu erhöhtem Energiebedarf, der eine immer größere Belastung für die Ökonomie des Landes darstellt, da Strom in Ägypten stark subventioniert wird. Zudem bieten die niedrigen Strompreise Anreize für einen immer höheren Energieverbrauch, wobei das Einsparen von Strom, die Einführung energieeffizienter Maßnahmen oder die Drosselung bei der Emission von Treibhausgasen vernachlässigt werden.

Dabei liegt Ägypten in einer Region, die ein großes Potenzial für erneuerbare Energien, besonders im Bereich Solar- und Windenergien, birgt. Es liegt fast im Zentrum des globalen Sonnengürtels und bietet daher ideale Voraussetzungen für die Nutzung verschiedener Arten von Solartechnologien, die nicht nur Wärmeenergie, sondern auch Kälte und Strom zu erzeugen imstande sind. Jedoch sind erneuerbaren Energie in Ägypten nicht sehr populär, was besonders für kleine bis mittlere Anwendungen wie die Baubranche gilt. Immer wieder wird das Argument vorgebracht, dass die Investitionskosten für erneuerbaren Energien zu hoch seien. Diese Dissertation möchte daher die energetische, wirtschaftliche und umweltfreundliche Effizienz konventioneller Ferienhotel-Modelle gegenüber neuartigem Solar-Ferienhotel untersuchen. Dafür sollten in mehreren Fünf-Sterne-Ferienhotels in Scharm el Scheich Energie-Audits durchgeführt werden. Von 36 Fünf-Sterne-Ferienhotels beantworteten nur 39% unsere Anfrage positiv und nahmen am Energie-Audit teil, wobei jedoch nur 19% verwertbare und schlüssige Informationen ablieferten. Ziel dieses Audits ist es, das Ausmaß derzeitiger Gestaltungsmaßnahmen zusätzlich zum Strom- und Wasserverbrauch pro Übernachtung in Scharm el Scheich zu erfassen. Die Resultate zeigen einerseits das Fehlen energieeffizienter Maßnahmen in den Feriendörfern von Scharm el Scheich und andererseits das Potenzial zur Reduzierung des Energieverbrauchs im Vergleich zu Zypern und Mallorca. Diese Informationen sind wichtig, um Bezugswerte heranziehen zu können und das vorschlagen Solar Ferienhotel-Modell zu entwickeln.

Um die verschiedenen Ferienhotel-Modelle ökonomisch und umwelttechnisch auswerten zu können, hat der Autor dieser Arbeit ein Ferienhotel-Bewertungsmodell ausgearbeitet, das auf den Lebenszykluskosten für Umweltfreundlichkeit basiert. Das Modell wird dementsprechend verwendet, um das herkömmliche Ferienhotel mit dem Solar-Ferienhotel-Konzept zu vergleichen. Es werden einige Was-geschieht-wenn-Szenarios durchgespielt, wobei die entscheidenden Parameter und ihr Einfluss auf die Resultate des Bewertungsmodells herausgearbeitet werden. Die Resultate zeigen, dass die Gesamtkapitalinvestitionskosten und die Lebenszykluskosten unter den derzeitigen Bedingungen im herkömmlichen Ferienhotel sehr viel niedriger liegen, während die entsprechenden CO_2-Emissionen durch Einführung des Solar-Feriendorf-Konzepts drastisch reduziert werden können. Sollten die Strompreise jedoch durch die Einführung eines neuen Energiegesetzes, den Wegfall der Subventionen und/oder den Anstieg der weltweiten Energiepreise steigen, werden auch die Lebenszykluskosten des her-

kömmlichen Ferienhotel-Modells so stark anziehen, dass Solar-Ferienhotels zusätzlich zu ihren umweltfreundlichen Eigenschaften auch finanziell attraktiver werden.

Die Arbeit schließt mit der Besprechung der Resultate und mit Empfehlungen dazu ab, wie man die Nutzung alternativer Energien im Hotelsektor in Ägypten attraktiver gestalten kann, um die erhofften umweltfreundlichen Wirkungen zu erzielen.

Stichwörter: *Bezugswert, CDM, CO2 -Emissionen, Ägypten, Energie-Audit, Energieeffizienz, Energieleistung, Energienutzung, Umweltfreundlichkeit, Auswertungsmodell, Hotels, erneuerbare Energie, Ferienhotels, Solar-Feriendörfer, Solararchitektur, nachhaltige Energie, Tourismus*

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List of Abbreviations

AC	Alternative current
B-a-U	Business-as-Usual
bcm	Billion cubic metres
CDM	Clean Development Mechanism
CER	Certified Emission reduction
CHP	Combined heat and power
COP	Coefficient of performance
CSP	Concentrated solar power
DC	Direct current
DHW	Domestic hot water
DNI	Direct normal irradiation
EEHC	Egyptian Electric Holding Company
EGAS	Egyptian Natural Gas Holding Company
EGP	Egyptian Pound
EGPC	Egyptian General Petroleum Company
ELCC	Environmental life cycle lost
EMS	Energy management system
EPP	Electricity purchase price
EUI	Energy use intensity
FAST	Function Analysis Systems Technique
FPP	Fuel purchase price
GDP	Growth domestic power
GHG	Green house gas
GN	Guest-night
GR	Guest room
GtR	Guest to room ration
GW	Gegawatt
GWP	Global warming potential
HVAC	Heating, ventilation and air conditioning
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
IRR	Internal rate of return
KPI	Key performance indicators
kWe	Kilowatt electric

kWh	Kilowatt thermal
LCA	Life cycle assessment
LCC	Life cycle cost
LPG	Liquefied petroleum gas
M&R	Maintenance & Replacement
MED	Multi-effect distillation
MJ	Mega joule
MSF	Multi-stage flash
MTOe	Mega Tonnes Oil Equivalents
MW	Megawatt
MWh	Megawatt hour
NPV	Net present value
O&M	Operation & Maintenance
PI	Profitability index
PP	Payback period
PV	Photovoltaic
PWA	Present worth of an annuity
RE	Renewable energy
REM	Resort evaluation model
RES	Renewable energy supply
REST	Renewable Energy and Sustainable Tourism
RETs	Renewable energy technologies
RO	Reverse Osmosis
RSSTI	Red Sea Sustainable Tourism Initiative
SME	Small & medium enterprises
SPS	Stand-alone power supply
TCI	Total capital investment
tCO_2	Tonnes CO_2
TDA	Egyptian Tourism Development Authority
TWh	Terawatt hour
USAID	US Agency for International Development
UWTO	World Tourism Organisation
VM	Value management
WACC	Weighted average capital cost
WECS	wind energy conversion systems

1 INTRODUCTION

1.1 Background

“Energy lies at the heart of the world’s economic development. Sound energy choices are, therefore, fundamental if we want to achieve sustainable development” (Fries, 2000). The world is becoming more aware everyday that not only resources are finite but also that the capability of natural systems to absorb society's wastes may be even a more stringent limit. With those two limitations, both developed and developing countries, who are striving to catch up with those developed ones, are faced with the challenge of overcoming those limitations. It is, therefore, essential for those countries to make wise technology choices.

This thesis explores the economical and technical feasibility of the Solar Resort concept in Egypt. The aim is to investigate the potentials of implementing self sufficient resorts in rural areas by using natural renewable resources.

The thesis is intended to be used a guidance document for project developers, investors, lenders, government authorities in the tourism sector who are interested and involved in promoting renewable energy in Egypt and environmental sustainability. It explores the main issues relative to the assessment and development of a solar resort. Different renewable energy technologies are investigated and assessed in terms of their viability for application in the hotel sector in Egypt with a special focus on the Red Sea region. The thesis also discusses briefly energy efficient measures in existing resorts and how future resorts should interact with the surrounding environment to reduce energy demands.

The perspective of the developer and the investor is mostly regarded throughout the study as more than any other party, they are the present stakeholders who determine whether a project would be developed using renewable energy or not.

This first chapter introduces the thesis by throwing light on the underlying drivers and relevant issues. It starts with an overview about the global energy problem and the role played by tourism industry in that aspect. This is followed by the thesis objectives and limits of scope.

At the end of the chapter, the research methodology is outlined explaining the procedure adopted in carrying out this study.

1.1.1 Global energy problem

The world energy demand is projected to grow dramatically over the coming decades and global warming is expected to intensify in the business as usual scenario. In 2007, oil prices rose continuously and set a new record at the end of the year. The causes behind this are complex, but continued growth of oil demand, especially in the transportation sector, is an essential background factor. Also, in 2007, the fourth assessment report published by the Intergovernmental Panel on Climate Change (IPCC) shows a higher confidence in global warming through anthropogenic green house gas (GHG) emissions. Moreover, continued extreme weather phenomena reported globally - including light snowfall, heavy rains, and persistent drought – were considered as a warning sign among the general public (Energy Working Group, 2008).

The International Energy Agency (IEA) has gathered frightening data on energy consumption trends. According to Pérez-Lombard, Ortiz, & Pout (2008) the primary energy consumption has grown during the last two decades (1984–2004) by 49% and CO_2 emissions by 43%, with an average annual increase of 2% and 1.8% respectively. Between 1990 and 2005, energy consumption grew most quickly in the service and transport sectors, both sectors showing an increase of 37%. These increases were driven by strong growth in activity in these sectors for many countries. Trends in CO_2 emissions are driven by the amount and type of energy used and the indirect emissions associated with the production of electricity. The global final energy consumption and CO_2 emissions increased by 23% and 25% respectively between 1990 & 2005 (IEA, 2008b).

Oil is the world's vital source of energy and will remain so for many years to come, even under the most optimistic of assumptions about the pace of development and development of alternative technology. But the sources of oil to meet rising demand, the cost of production it and the prices that consumers will need to pay for it are extremely uncertain, perhaps more than ever. Preventing catastrophic and irreversible damage to the global climate ultimately requires a major decarbonisation of the world energy sources. IEA has declared that on current trends, energy-related emissions of CO_2 and other greenhouse gases will rise inexorably, pushing up average global temperature by as much as 6°C in the long term (IEA, 2008a).

The scientific evidence on the need for urgent action on the problem of energy security and climate change has now become stronger and convincing. Thus, it is not within the scope of this thesis to extensively discuss this evidence in detail.

Future solutions, for energy security and environmental sustainability, would lie in the use of renewable energy technologies, greater efforts at introducing energy efficiency measures and, finally but not least, policy formulation and implementation. Policies can neither be implemented nor promoted without technology research and development nor without economic viability and market reform.

1.1.2 Tourism industry & energy consumption

The rapidly growing building industry has already raised concerns over supply and depletion of energy resources and heavy environmental impacts (ozone layer depletion, global warming, climate change, etc.). The global contribution from buildings towards energy consumption, both residential and commercial, has steadily increased reaching figures between 20% and 40% in developed countries, and has exceeded the other major sectors: Industrial and transportation (Pérez-Lombard, et al., 2008).

The IEA statistics for energy balance for 2004-2005 show that the total final energy use globally accounts for 7,209 Mtoe (Mega Tonnes Oil Equivalents). The residential and commercial sectors account for respectively 1,951 Mtoe and 638 Mtoe, which is almost 40 % of the final energy use in the World (Figure 1-1). The major part of this consumption is in buildings (IEA & Laustsen, 2008).

Buildings – be they homes, hospitals, schools, universities, workplaces or spaces in which to relax – are responsible for around 40% of all world resource consumption and over 40% of all waste, including GHG emissions (Greenhotelier, 2005).

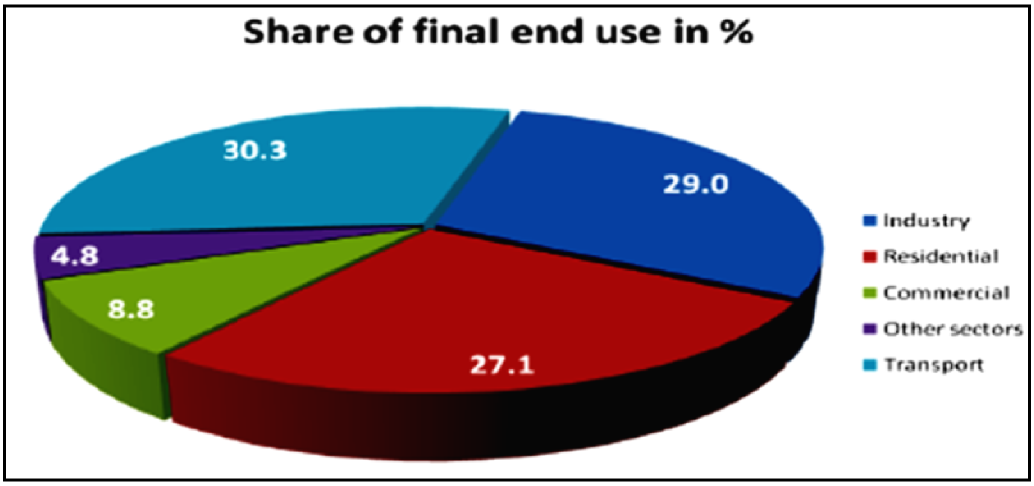

Figure 1-1: Energy consumption in different sectors (IEA & Laustsen, 2008).

Although no collective data is available on the global energy consumption in the hotel sector, Gössling (2002) estimated that 97.5 TWh (Terawatt hour) of energy was used in hotel facilities worldwide in 2001 (Paulina Bohdanowicz & Martinac, 2007). In 2000, almost 700 million international tourist arrivals were counted worldwide. Even though a global activity of this scale can be assumed to have a substantial impact on the environment, its consequences have never been assessed and quantified (Gössling, 2002). Another study indicates that European hotels alone consume approximately 39 TWh/year (CHOSE, 2001).

Studies indicate that the high energy consumer in the tourism sector is transportation followed by accommodation and other activities as shown in Table 1-1.

Category	**Energy use (PJ)**	**CO_2-e emissions (Mt)**
Transport (incl. ship, etc.)	13,223	1263
Accommodation	508	81
Activities	350	55
Total	14,081	1399

Table 1-1: Global tourism-related energy use and resulting $CO_{2\text{-}e}$ emissions (Gössling, 2002)

Hotel units are among the largest energy consumers in the building sector, where energy planning may greatly facilitate investment decisions for efficiently meeting energy demand (Mavrotas, Demertzis, Meintani, & Diakoulaki, 2003). Hotels use generally more energy per visitor, as they have energy intense facilities, such as bars, restaurants, and pools, and more spacious rooms. Accommodations in the category ‘pensions’ may have a comparably low number of beds and occupancy rates are assumed to be somewhat lower than those of hotels (Gössling, 2002).

It is further believed that a significant amount of the energy used in this sector is wasted, leaving ample room for enhancing energy-efficiency and resource conservation.

Accommodation Establishment	Energy use per bed night (MJ)	Beds (millions)	Bed nights (millions)[a]	Energy use (PJ)	CO_2-emissions (mT)[b]
Hotels	130	15.98	2700.6	351.1	55.7
Campsites	50	9.05	995.5	49.8	7.9
Pensions	25	4.06	686.1	17.2	2.7
Self-catering	120	3.62	611.1	73.4	11.6
Holiday villages	90	0,75	126.8	11.4	1.8
Vacation homes	100	0.68	49.6	5.0	0.8
Total	_	34.14	5170.4	507.9	80.5

[a] A global occupancy rate of 46.4% was assumed here for the categories hotels, pensions, self-catering, and holiday villages (calculated from data provided by WTO (2001) for 159 countries for the years 1995–1999); for campsites, a lower occupancy rate of 30% was assumed, taking into consideration strong seasonal variations, and for vacation homes, an occupancy rate of 20% was used.

[b] Based on an emission factor of 43.2 g C/MJ (Schafer and Victor, 1999for the 1990 world electricity generation mix).

Table 1-2: Global energy use accommodation (Gössling, 2002)

1.1.3 Growth of tourism development

Over the past six decades, tourism has experienced continued expansion and diversification to become one of the largest and fastest growing economic sectors in the world. In spite of occasional shocks, international tourist arrivals have shown virtually uninterrupted growth – from 25 million in 1950, to 277 million in 1980, to 438 million in 1990, to 681 million in 2000, and the current 880 million. The fast growth, particularly evident in the world's emerging regions, resulted in a steady rise in their share of received international tourist arrivals, from 32% in 1990 to 47% in 2009 (UNWTO, 2010).

The Middle East has been one of those fastest growing regions in the past few years. The World Tourism Organisation (UWTO) expects a growth rate of 7.1% in the number of tourism visiting the Middle East (Figure 1-2).

In Egypt, tourism is recognized to be one of the largest contributors to it its economic growth. It has grown rapidly and almost continuously over the past twenty years. It particularly benefits the Egyptian economy, where most of the sector's new tourism jobs and businesses are being created.

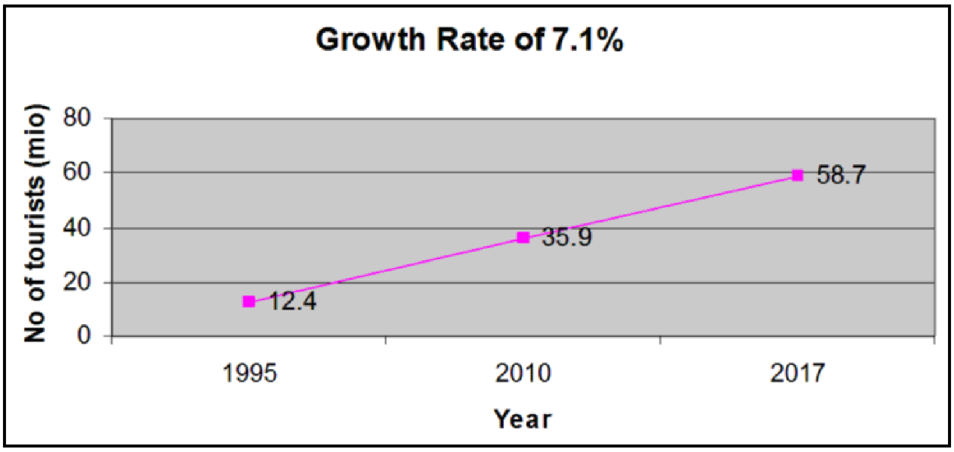

Figure 1-2: Expected tourism growth rate in the Middle East (UNWTO).

1.2 Thesis objective: Sustainability & solar resort concept

Greenhotelier (2005) defines sustainable development as the development that can satisfy the needs of the present generation without compromising the ability of future generations to meet their needs. If too much energy and water are consumed and the environment is continuously polluted, then others would be deprived of the natural benefits that we have enjoyed.

Sustainable Tourism is defined by the Organization of Eastern Caribbean States as the optimal use of natural and cultural resources for national development on an equitable and self sustaining basis to provide a unique visitor experience and an improved quality of life through partnership among government, the private sector and communities (OECS).

Sustainability is becoming an important focus being directly related to resources available and how those resources are used today and how they will be used in the future. The concepts and application of sustainability are an important component in the management of any business (Lockyer, 2007).

Hotels are heavy users of resources and heavy polluters. The impacts caused by the development of a hotel have been demonstrated in many research projects. There is now a growing interest in 'green' hotels to reduce the impact hotels have on society and the environment, although much of the push is simply an attempt to reduce costs (Lockyer, 2007).

The idea of a sustainable resort is based on improving processes to the point of maximum resource productivity and virtually no waste in addition to reducing the dependency on fossil fuel. The goal is to reduce consumptions, wastes and emissions, while preventing harm to environmental and human health.

Based on the previous sustainability principle, the concept behind solar resort is to combine the most suitable environmentally sustainable architecture and technologies while providing excellent service and luxurious accommodation.

Although the solar concept is technically proven, remains the question often raised whether it is an economic and profitable goal. The study carried out within this thesis addresses the issue: *Is sustainable and solar resorts an achievable goal?*

The main objective of this thesis is to evaluate the current state of energy consumption in resorts on the Red Sea coast and develop an evaluation model for resorts with regards to energy consumption, CO_2 emissions and cost of implementation and operation.

The thesis raises the following questions:

1. Can renewable energy cover the energy demand of a five stars resort, located on the Red Sea coast in Egypt?
2. Which environmental technologies are the most suitable in that case?
3. Which is the most economical scenario of renewable energy mix?
4. What are the financial indicators for such scenarios?
5. What is the environmental impact?
6. Can Clean Development Mechanism (CDM) improve the chances of financial success of such a solution?

1.3 Limitations of the research

In view of the previously mentioned issues, the topic under study is extensive and interrelated to many aspects such as, but not limited to, energy consumption, efficiencies, materials, design concepts, technologies, and location & types of hotels. Therefore, it is necessary to define the boundaries of this thesis and the limits to the scope of investigation.

The research focuses on the feasibility study stage of a project rather than detailed engineering and, accordingly, does not discuss technical issues in details for example types of construction materials, processes, methodology and their influence on energy consumption. The civil engineering and architectural aspects, involved in the development of any resort, have been extensively addressed through researches on green or environmental buildings and solar architecture and do not constitute part of this investigation. This investigation focuses on the selection of energy production systems of a resort which have a direct impact on the energy performance. Yet the model developed through this research does not present thermodynamic simulations but rather used for economical and environmental evaluation by decision makers.

UNEP & Wood (2002) describe ecotourism in the marketplace, from a functional viewpoint, as mostly individual or small-scale tourism (tour groups up to 25, and hotels with less than 100 beds) which is operated by small-medium-sized companies in natural areas. This thesis however does not consider ecotourism in its research rather it focuses on larger bed capacities starting from 200 beds. The research is also limited to investigating resorts classified as five stars since they represent the highest consumers among the accommodation sector in tourism.

The town of Sharm el Sheikh is chosen to represent resorts developed on the Red Sea coast for the following reasons:

- It represents one of the most intensively developed areas over the last two decades.
- Being one of the most attractive areas on the Red Sea visited by international and local tourists, many of the newly developed areas such as Marsa Alam tend to follow the same design concepts adopted in Sharm el Sheikh.
- Author’s own experience with resorts development in Sharm El Sheikh from 2000 to 2005 which represents the peak period of Sharm el Sheikh’s development
- Easier access to data and better response to interview requests.

Other touristic areas in Egypt are not considered within the scope of this study.

Accordingly, the scope of research in this thesis is limited to investigating the influence of technology selection and its economic feasibility in terms of energy production systems used in a resort located on the Red Sea coast in Egypt and their environmental impact.

1.4 Research methodology

The hypothesis of this research is to model, economically and environmentally, solar resorts and compare it to conventionally designed resorts. Several models do exist for evaluating a specific single technology for any type of project, however, there are no models specifically developed for resorts evaluation neither are there models that take into account the synergy effect of combining a mix of various environmental technologies.

Figure 1-3 illustrates the research methodology adopted in carrying out this thesis. The first three phases involve compiling of information which forms the basis of the work. The last four phases deals with the design development, modelling, analysis and evaluation of the proposed solar resort.

The literature review covers the three main issues discussed within this study and are presented in chapter 3. The review explains the scope and the extent to which those issues have been addressed so far. It also provides an indication of the issues that need to be further investigated and areas where lack of information was apparent. A literature review was carried out to gather this information. The objective of the literature review is establishing the common elements of good practice in the tourism sector globally as well as locally in the Red Sea region. The literature review searches for answers to the following issues:

1. Energy consumption of resorts and hotels:
    a. The average energy consumption, resources and efficiency status worldwide
    b. The average energy consumption, resources and efficiency status in Egypt and the Red Sea region.
2. Solar design of resorts and hotels
    a. The extent of applying renewable energy in resorts and hotels
    b. Review of existing solar resorts and their design concepts
3. Environmental technologies
    a. What types of technologies commercially exist?
    b. What are their installation and operation costs?
    c. What constraints are associated with such technologies?

In order to evaluate the current performance of existing resorts on the Red Sea coast, a transparency of information about cost and consumptions is required. However, due to the lack of information about resorts and their performance in Egypt, the author carried out a survey with the aim of collecting the requited information. The survey is explained in more details in chapter 4.

The data gathered from the resorts in Sharm el Sheikh are analysed determining their energy performance and water consumption. The outcome of the data gathering and analysis will be used to establish a business-as-usual case representing a typical resort.

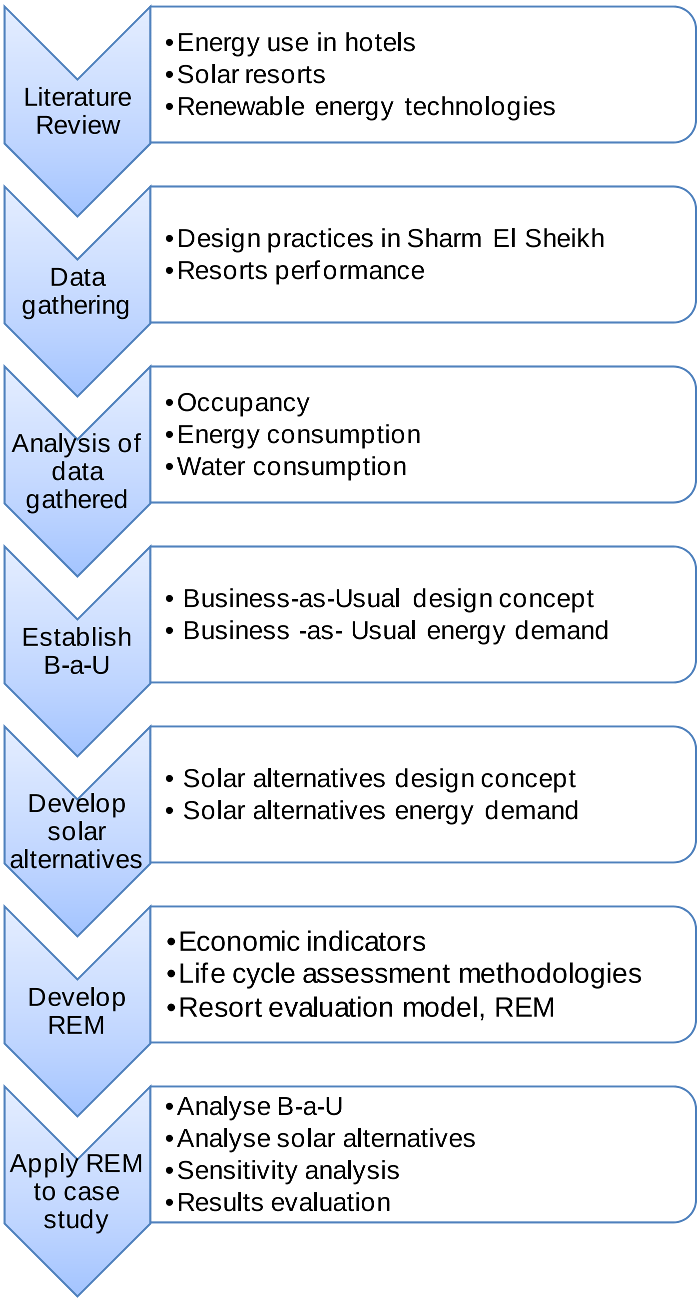

Figure 1-3: Research methodology

Alternatives using the proposed solar design concept are developed with energy-engineering as well as environmental and economic perspectives in mind. A value management exercise is carried out on the business-as-usual case in order to highlight the areas that need to be addressed and optimised. The results of literature review are also used in this stage in the development of the proposed solar resort design where different elements are integrated and combined.

A resort evaluation model is developed based on environmental life cycle costing analysis. The model is used to evaluate the economical and environmental viability of the different design alternatives. Sensitivity analysis will determine the critical parameters affecting the outputs of evaluation model.

The outcome of the research is an evaluation model used in decision making and realising the real options during the first stages of planning and design of resorts when detailed engineering is not available.

2 Problem Definition

This chapter presents an insight into the driver of this thesis. It explains where the author envisages a problem and what the future could hold in the energy and tourism sector. It starts with an overview on the current and forecasted status for each of the energy and tourism sector in Egypt. The problem is accordingly defined and the potential opportunities are highlighted. Figure 2-1 shows an outline of the chapter's structure and content.

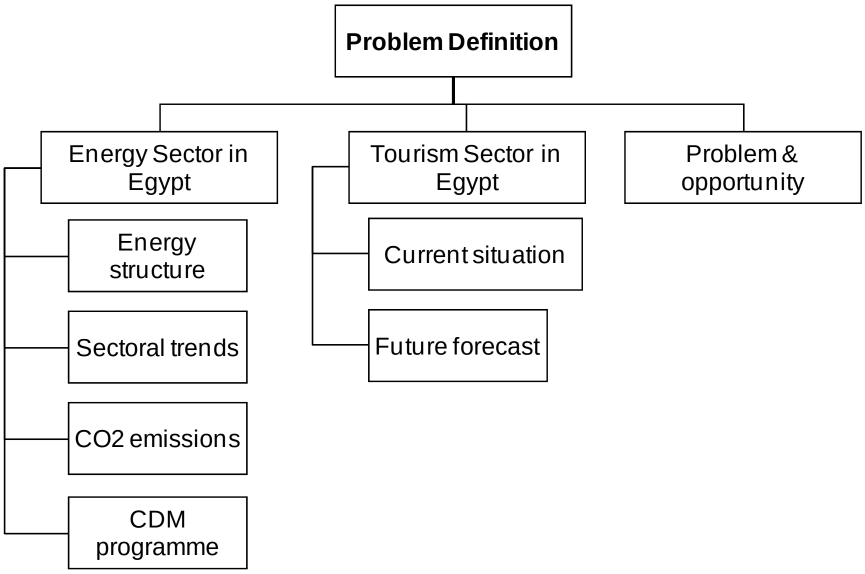

Figure 2-1: Outline of chapter 2

2.1 Energy in Egypt

2.1.1 Background

Egyptian economic has been strongly growing in recent years and its growth domestic product (GDP) grew in 2004 to around 4%. This growth might have slowed slightly in the wake of the terrorist attacks particularly in the tourism sector, yet, there is a growing demand for electricity (EIA, 2006).

Egypt's energy mix is dominated by oil and gas, which is expected to continue so until 2030 accounting for 95% of primary energy demand. Energy demand in Egypt is projected to grow from 54 Mtoe in 2003 to 109 Mtoe in 2030, at an average annual growth rate of 2.6% (IEA, 2005).

Meanwhile, Egypt has an extensive system of social subsidies amounting to 26.3 billion Egyptian pounds in 2004 (roughly 2% of GDP). These subsidies cover a variety of sectors, including the energy sector (petroleum products and electricity) which account for the bulk of the subsidies (IEA, 2005) (Figure 2-2). Although, the government has increased the price of diesel by 50% over the past years, yet it still remains below the cost. Subsidies in general do present a burden on the country's budget while they encourage growth in energy demand and consumption.

Energy-intensive industries have received significant subsidies to maximise their competitiveness in international markets. Decrees by the Egyptian Prime Minister in 2007 and 2008 called for complete elimination of these subsidies within three years. However, the current global financial crisis has prompted the government to switch from a speedy elimination of subsidies to a more gradual approach. Moreover, a five-year plan for reducing subsidies to residential consumers and small & medium enterprises (SMEs) is under way (Environics, 2010).

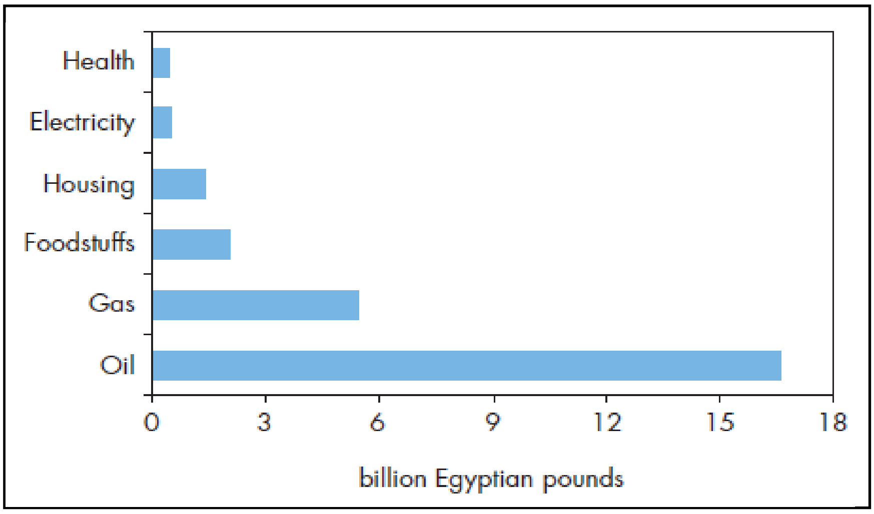

Figure 2-2: Social subsidies in Egypt, 2004 (IEA, 2005)

Passage of a proposed new electricity law, under consideration since April 2008, appeared imminent as of late 2009. This law will establish the legal framework for major structural changes in Egypt's energy sector, which will create a more liberalised energy market and a more-secure energy supply. It furnishes the legal grounds for private sector involvement in generation and distribution activities. This strategic option is justified on the basis of shifting the burden of developing the energy sector away from the state and towards creating an environment that can better benefit from international energy technologies and institutions. Feed-in tariffs, determined by the cabinet, will be guaranteed for the electricity produced and sold into the grid. This feed-in tariff system will probably come in a later phase, following a learning period under the new structure. It is expected that this initial phase will eventually lead to achieving balanced optimum prices for renewable energy (Environics, 2010).

2.1.2 Energy structure

Egypt's power sector is dominated by the Egyptian Electricity Holding Company (EEHC) which was set up in the year 2000 as part of plans to liberalise the electricity sector. These plans are progressing very slowly, even though private sector participation in power generation has been possible since 1996, notably through independent power projects (IEA, 2005).

Egypt started generating electricity from hydraulic sources when Aswan Reservoir Station was established in 1960 at a capacity of 340 MW (Megawatt) followed by the High Dam Station in 1968 with a capacity of 2100 MW. This hydraulic source of energy contributed in making a great industrial up raise and in lighting a great part of the Egyptian rural area during that period. In 1985, there was an expansion in hydraulic power generation stations, where Aswan Reservoir Station II, Esna and Nagaa Hammadi stations were built. In 2005/2006, a barrage for electricity power generation at Nagaa Hammadi with a capacity of 64 MW and the completion of renewing the turbines of the High Dam Station were being implemented. Hydraulic

Power Plants constitute about 18 percent of the total consumed electric power in Egypt (IEA, 2005).

On the other hand, 27 thermal power plants, that use oil and natural gas, were established during the past two decades. The share of gas increased substantially in the late 1990s, following substantial foreign investment in Egypt’s gas sector and the decline in oil production. Today nearly 80% of electricity is based on natural gas. In 2003, oil-fired power generation accounted for about 6% of the total generated power while hydropower plants for 14%. The total installed generating capacity was 18 GW (Gegawatt) in 2003, most of which are gas-fired boilers. The few hydropower stations accounting to 2.7 GW of installed capacity are mostly located in Aswan, where dams have been built to control flooding of the Nile River. In 2004, the wind power capacity installed in Egypt reached 140 MW in 2004 (IEA, 2005).

The announced energy policy in Egypt during the current stage aims at preserving the coming generation right to the traditional depletable energy sources and making the best use of various energy alternatives through giving due attention to using new and renewable energy sources to produce clean energy. In April 2007, Egypt's Supreme Council of Energy announced an ambitious plan to generate 20% of the country's electricity from renewable sources by 2020, including a 12% contribution from wind energy, translating into 7,200 MW of grid-connected wind farms.

On the other hand, Nuclear power is enjoying an upsurge in interest in Egypt which officially announced in September 2006 its intention to resume its nuclear programme which had been frozen since the 1986 Chernobyl disaster. A 1,000 MW power station at Al-Dabah has been proposed by the Minister for Electricity and Energy.

Egypt is at energy cross-road; it faces choices about what energy sources it will use in the future. Conventional fuels are becoming increasingly expensive and there is recognition that these fuel resources are finite. Some estimates indicate that indigenous natural gas and oil reserves, on which Egypt's electricity generation currently relies, will run out in about 30 or 40 years, making the transition to alternative energy sources a pressing need to avoid stagnant economic development (Greenpeace, 2007).

Since 1996, Egypt has allowed private sector participation in power generation, through build-own-operate-transfer, BOOT, projects where independent power producers must sell wholesale electricity to the government-owned power company for a twenty-year period of time and transfer all assets to it at the end of that period.

Egypt’s current structure as a captive energy market, in which the government is a single buyer and almost holds a monopoly on the generation; transmission and distribution of power, is not advantageous for the establishment of a growing renewable energy (RE) regime. However, this new proposed electricity law, now in the process of being ratified, and its associated changes in the energy market structure, promises incentives for private sectors to participate in Egypt’s energy market including RE (Environics, 2010).

As a result of the highly subsidised energy prices, the prices of electricity in Egypt range among the lowest in the world. The prices are fixed by the Egyptian government in a non-transparent manner and apply in equal manner to all regions. The average tariff for the residential sector, across all consumption levels was 1.84 US cents per kWh in 2003. Since October 2004, several electricity tariffs were raised by an average of 8.6 % for the first time since

1992 and further 5 % increases were set for all electricity customers for each of the following five years. The last increase took place in November 2008. In 2008, the rise summed up to 7.5 %, including an additional 2.5 %-increase caused by high oil prices. The governmental plan was intended to gradually accommodate the electricity prices to the actual cost of the electricity system. However, taking into consideration annual the inflation rate exceeding 5 %, these increases may not be sufficient. The new electricity law is intended to define the main principles of price regulation such as the ones mentioned above (ECOFYS, 2009).

Although Egypt did embark on an economic adjustment program to address its low energy prices by correcting a costly subsidisation policy that kept prices from rising and which encouraged increasing energy consumption, it is not transparent to which extent this program would be implemented due to political and social reasons.

2.1.2.1 Fossil fuel in Egypt

Most of Egypt's hydrocarbon reserves are state-owned and controlled by the Egyptian General Petroleum Company, EGPC, or the Egyptian Natural Gas Holding Company, EGAS. As oil production is now in decline, the focus of the Egyptian energy sector has shifted to the development of the abundant natural gas resources.

Egyptian oil production peaked over a decade ago and has since been in decline. Production is expected to fall from 0.7 mb/d in 2010 to 0.5 mb/d in 2030 and Egypt, currently a minor oil exporter, would then become a net oil importer by around 2015 (IEA, 2005) (Figure 2-3; Figure 2-4).

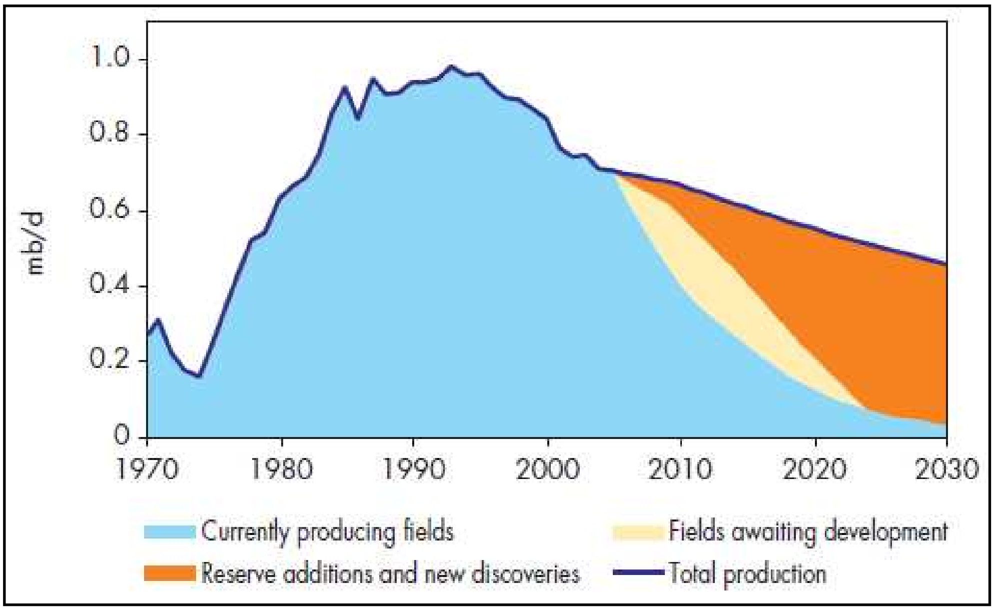

Figure 2-3: Egypt's oil production by source (IEA, 2005)

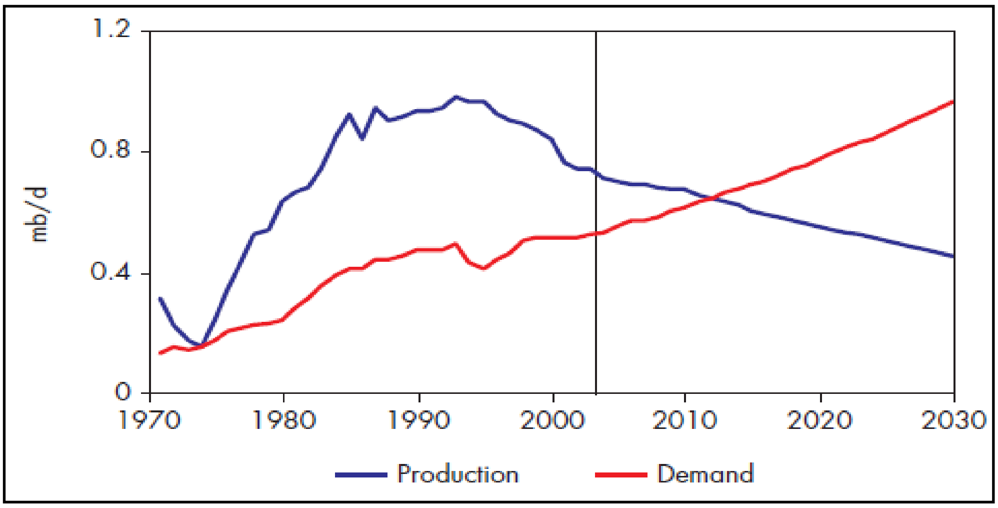

Figure 2-4: Egypt's oil balance (IEA, 2005)

Meanwhile, Egypt, with 1.9 tcm (cubic metres) of natural gas reserves, is of increasing importance in the global gas market. Production is expected to treble, reaching 50 bcm (billion cubic metres) around 2010 and over 90 bcm by 2030. Natural gas exports started in 2005 and are expected to increase significantly, reaching 28 bcm by 2030 (Figure 2-5). The reliance on natural gas is expected to increase with the expected increase electricity generation from 92 TWh in 2003 to 188 TWh in 2030.

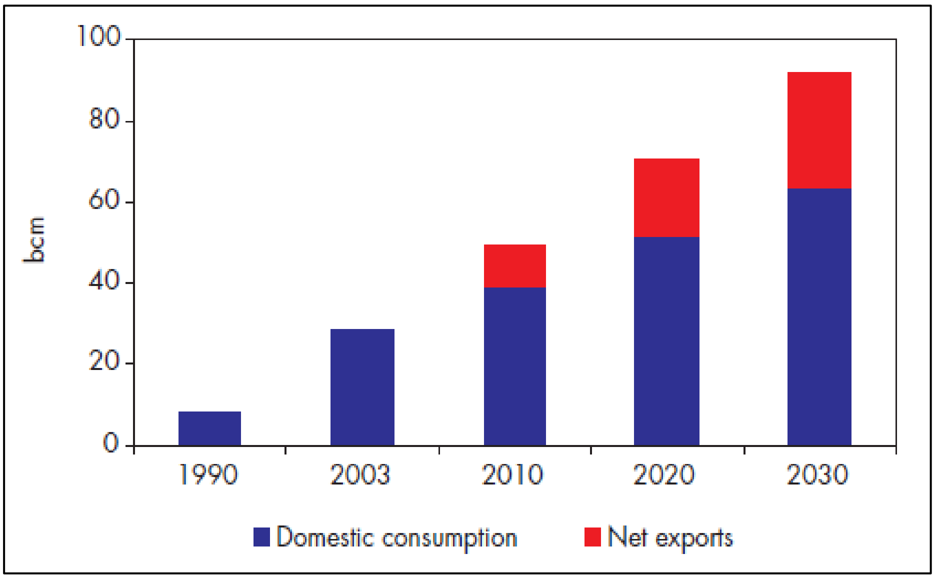

Figure 2-5: Egypt's natural gas balance (IEA, 2005)

2.1.2.2 Renewable Energy

RE sources in Egypt are mainly wind, solar and biomass. In 1982, the RE strategy announced a target of covering 3% of the national electric demand by RE by the year 2010. The aim was to take advantage of renewable energy environmental benefits allowing financial support of its projects implementation through various mechanisms such as CDM, financing RE incremental cost, soft loans, mixed credits etc. However, today in 2010, the actual share of renewable energy has reached 1% only (Figure 2-6).

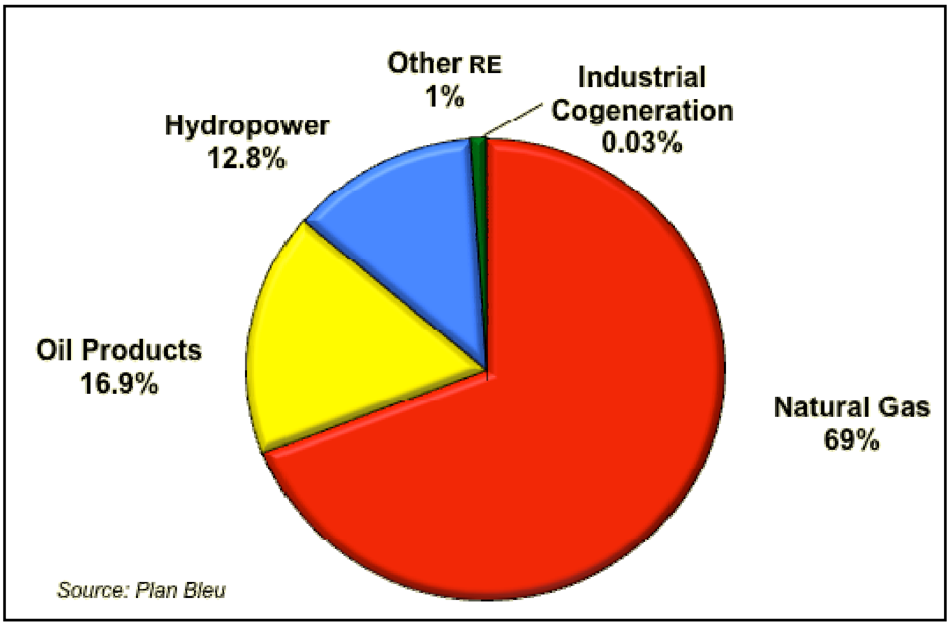

Figure 2-6: Share of Egyptian power generation by capacity in 2006/07 (Environics, 2010)

The amount of electricity produced in Egypt per year based on 2004 figures is 91.72 billion KWh and the amount consumed is 84.49 billion KWh (CIA). Considering all types of renewables available in Egypt, the total economically available renewable energy resource in Egypt is 7,573 billion KWh per year which is over 80 times the amount of electricity produced per year (DLR, 2005). This is actually half the technically available renewable resource which implies that as renewable energy technologies improve, twice this amount will become available i.e. 15,086 billion KWh as indicated in Table 2-1 .

Hydro		**Geo**		**Bio**		**CSP**		**Wind**		**PV**	
Tech	Econ	Tech	Econ	Tech	Econ	Tech	Econ	Tech	Econ	Tech	Econ
80.0	50.0	n.a.	25.7	n.a.	15.3	73656	73656	7650	90.0	n.a.	36.0

Table 2-1: Technical & economical renewable electricity supply side potentials in TWh/year (DLR, 2005). Hydro – hydropower; Geo – Geothermal; Bio – biomass; CSP – concentrated solar power; wind – wind power; PV – photovoltaic

Egypt's primary locations offer 2,400 or more hours of solar operation, compared with maximum European figures of 1,900 in Spain and Greece, the next-closest countries. As for wind energy, hours of operation in areas with the highest speeds can reach up to 3,900 hours per year (GAFI, 2010).

The amount of solar radiation available in Egypt is between 1900 KWh/sq.metre/year in the north and 2600 KWh/sq.metre/year in the south. If the average for the country is taken as 2300 KWh/sq.metre/year then there is at least 230 billion KWh of solar radiation – over two and a half times the amount of electricity produced for the whole country (NREA). Figure 2-7 shows that Egypt among its North African neighbouring countries is well positioned for producing power through solar energy.

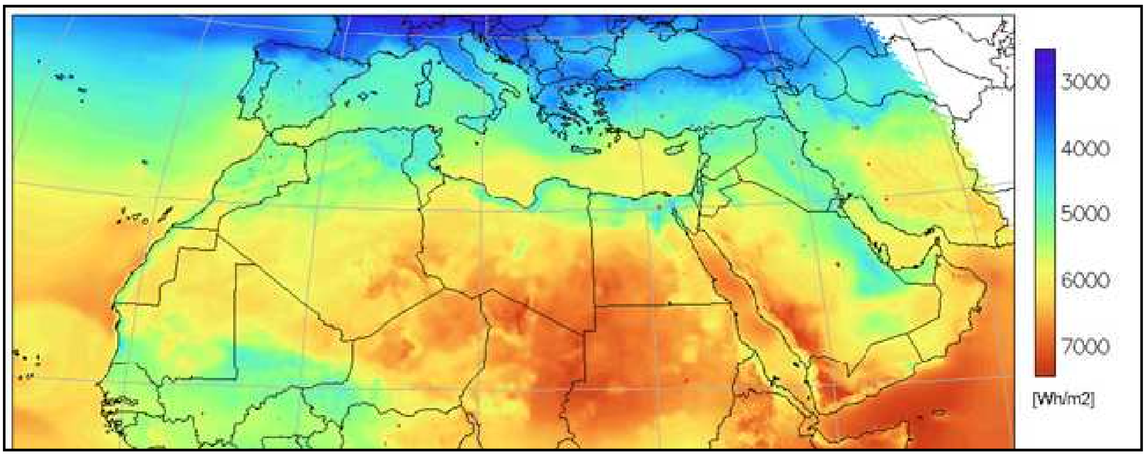

Figure 2-7: Solar electricity potential in Egypt and North African countries (Huld, Šúri, Albuisson, & Wald, 2005)

Solar energy meets a small part of demand in the residential and services sectors. There are more than 200,000 solar water-heating systems in use in houses, the commercial sector, new cities and tourist villages. The potential is much larger. Solar heat is projected to reach 0.1 Mtoe in 2030 (IEA, 2005).

With Egypt producing almost 57% of the region's total wind energy, it has already become the leading producer - ahead of Morocco, Iran and Tunisia. Furthermore, the Suez Canal area has one of the highest consistent wind speeds in the world at 10 m/s. Other important areas include the Western and Eastern deserts, in addition to the Red Sea coast along the Gulf of Aqaba (GAFI, 2010).

On several occasions, the government announced that it expects the renewable energy sector to produce 20% of total power generation by 2020. Priority sectors are wind farms as they are considered the most cost-effective renewable energy source; followed by biodiesel production, both of which are supported by the country's abundance of land, stable climate conditions and competitive labour force. With solar energy costs expected to decline sharply over the next 5 to 7 years, Egypt aims to develop a competitive market in solar energy, but sees more immediate opportunities in wind and biomass (NREA).

2.1.3 Sectoral trends

In 2003, the residential and services sectors accounted for around a quarter of total final consumption. Electricity consumption stood at 4.0 Mtoe and oil consumption, mainly in the form of LPG, stood at 3.9 Mtoe. These two fuels accounted for 88% of energy consumption, renewables for another 8% and natural gas for the remainder (IEA, 2005). Figure 2-8 illustrates the energy use by sector for the period 2003-2004. Although the industry sector is the highest consumer, yet households and commercial sector have a significant share.

With the expected increase in the electricity demand at 2.8% per year, the increasing importance of tourism and the services sector in the Egyptian economy will spur nevertheless additional electricity consumption.

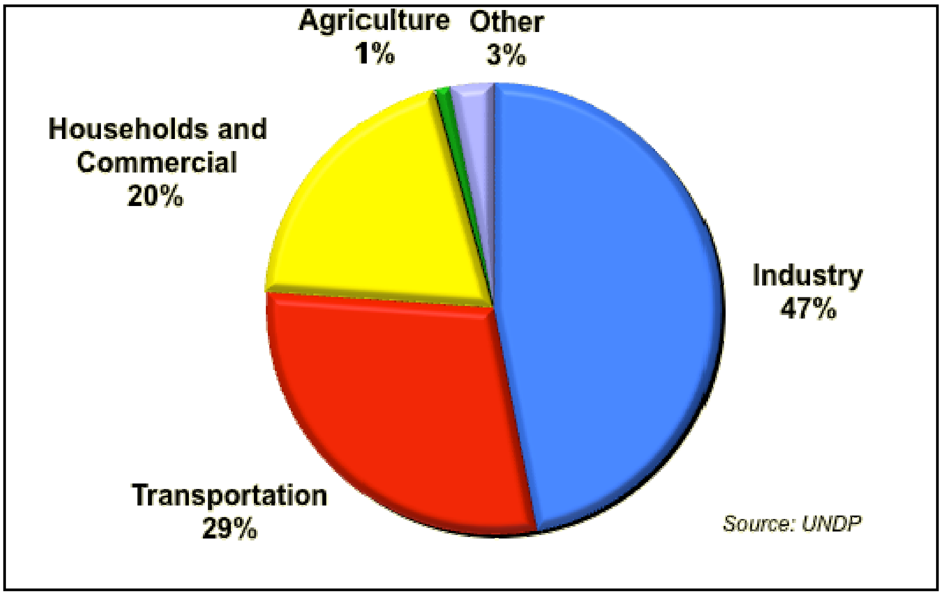

Figure 2-8: Share of Egypt's energy use by sector 2003/2004 (Environics, 2010)

2.1.4 CO_2 Emissions

The IEA (2005) projects an increase in Egypt's CO_2 emissions at an average annual rate of 2.6%, from 122 Mt (Million ton) in 2003 to 151 Mt in 2010 and 242 Mt in 2030. The main emitters of GHG in Egypt are fuel combustion accounting to 22% in the energy sector; 21% in the industry sector and 18% in the transport sector. In total, energy-related emissions are responsible for 71% of the GHG emissions in Egypt (CD4CDM, 2006).

On the basis of these rough assumptions for all sectors, the total GHG emissions of Egypt are expected to rise to 345% above 1990 levels until 2017, a projected increase typical for developing countries. The energy sector is expected to remain by far the major source for GHG emissions in the future and to increase its share with the highest growth rate (Barakat, Saad El-Din, & Elewa, 2003).

2.1.5 Clean Development Mechanism in Egypt

CDM is a global mechanism under the Kyoto Protocol that enables investors to receive credit toward their own GHG emission reduction obligations. Those reductions can be traded in the emerging global carbon offset market. In order to produce adequate and credible reductions, it must be demonstrated that CDM projects would bring down emissions per unit of output, measured in tonne of CO2 equivalents per MWh (Megawatt hour), to a level below that of the baseline scenario which would have existed in the absence of the CDM project. The emission reductions generated by a CDM project are thus the amount of GHG emissions that is avoided by implementing a renewable energy alternative that displaces electricity generation from power plants that are built and operated under business as usual conditions and are fuelled by either coal, oil, or natural gas (Ringuis et al., 2002).

It is seen that small-scale projects will be fast tracked through the CDM approval process. The preliminary rules in this area were first formulated in 2001. They define three categories of small-scale CDM projects as follows:

1. Renewable energy project activities with a maximum output capacity equivalent of up to 15 MW
2. Energy efficient improvement project activities which reduce energy consumption, on the supply and/or demand side, by up to the equivalent of 15GWh/year
3. Other project activities that both reduce anthropogenic emissions by sources and that directly emit less than 15 kilo tonnes of CO_2 equivalent annually.

CDM may stimulate considerable investments by using renewable energy technologies (RETs) reducing GHG emissions in developing countries. The CDM's impact on a project's finances depends both on the baseline and on the offset price.

A few CDM projects have been introduced in Egypt but are still not wide spread, especially across the private sector. CDM projects could provide Egyptian investors with an important incentive for reducing their CO_2 emissions through better efficiencies and use of renewable energy. An extensive survey for identifying projects in the targeted promising sectors and technologies has been carried out, and resulted in the following list of proposed CDM project types for Egypt (CD4CDM, 2006):

- Co-generation in textile, chemicals, food and beverage, metals, buildings, and **hotel sectors**
- Energy efficiency in textile, chemicals, food and beverage, metals, buildings, and **hotel sectors**.
- Fuel switching to natural gas in industry and transportation.
- Organic waste management and municipal solid waste methane utilization.
- Forestation projects.

Using relatively disaggregated data on the Egyptian electricity system, the Systems Analysis Department at Risø National laboratory estimated an emission rate ranging from 0.61 tCO_2/MWh to 0.59 tCO_2/MWh in Egypt. These results are very similar to the estimates based on other interpretations (Ringuis, et al., 2002).

2.2 Tourism Sector in Egypt

Egypt has always been a country of tourism where foreigners used to visit and see its antiquities dating back to the various eras and civilizations. However, over the last 20 years, recreational tourism domain has grown rapidly at several unique destinations such as Sharm El-Sheikh, Hurghada, Safaga, Taba and others places located on both the Red Sea and the Mediterranean Sea as well. Moreover, Egypt is renowned for therapeutically and environmental tourism as well as other kinds such as Safari, conferences and sports.

The tourism industry represents one of the most important features of the national economy formula. According to the Central Bank of Egypt, tourism is one of the most important export sectors in Egypt where it resembles 36.4% of the total exported services and accounts for 23% of the country's foreign currency income. In addition, tourism creates 2.2 million job opportunities, making it the locomotive of the economic development process (MoT, 2006).

2.2.1 Current Situation

The Egyptian Ministry of Tourism predicts a continuous growth in the tourism sector based on the constant growing trend in the previous years. Figure 2-9 depicts the development of tourists' number over the last 10 years (MoT, 2006).

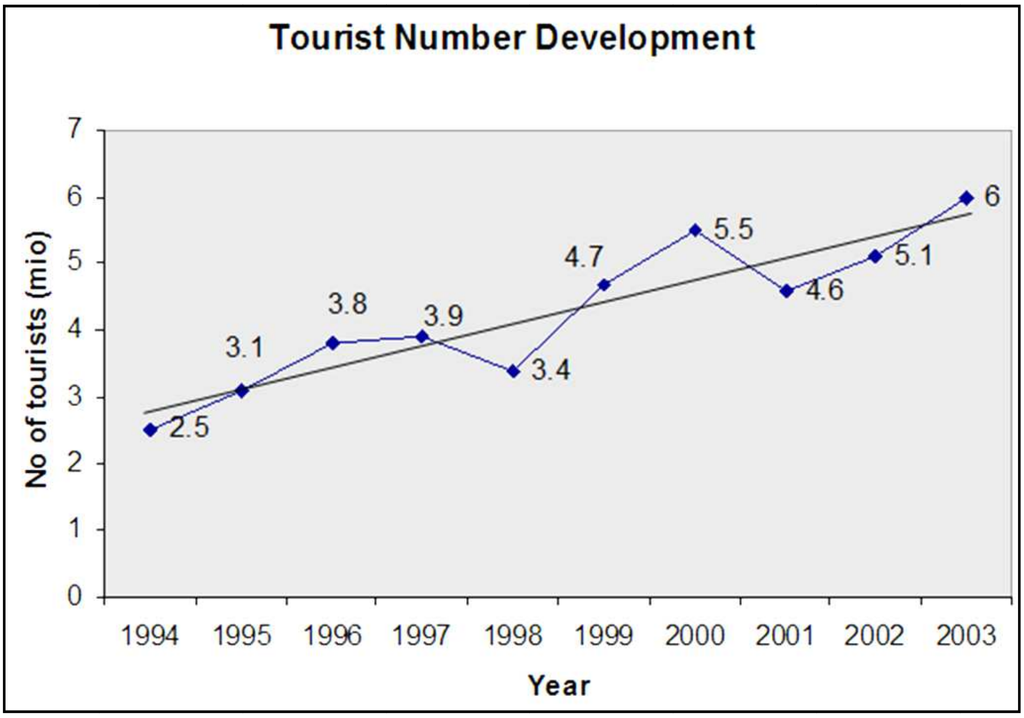

Figure 2-9: Tourist number development (MoT, 2006)

In the meantime, the main target for expanding the tourism sector is nature-based tourism. The coral reefs and rich marine life in South Sinai and the Red Sea coast have made these two areas among the premier scuba diving destinations in the world. Many beach resorts are now in operation and there are still hundreds to be constructed. Recognizing its potential as a destination for nature-based tourism, Egypt is currently developing the Red Sea Coast region, which was until recently considered a remote non-inhabited area of the country. Until recently, the Red Sea region had very few economic activities and was one of the least populated regions of Egypt. These activities include offshore oil exploration, phosphate mining, and fishing on a limited scale. Starting from the early 1990s, the Red Sea region has been targeted for massive tourism development in Egypt. In 2000, the existing number of rooms was 10,549 representing 22.2% of the total hotel accommodation capacity in Egypt. The target for 2012 is to achieve 140,000 rooms primarily by constructing new resorts and secondly by expanding the existing ones (Shaalan, 2005). Being one of Egypt's premier tourism destinations, the Red Sea receives over 1.2 million tourists visit the Red Sea coast in Egypt annually (USAID).

The investment in the tourism sector for the 2005/2006 years is estimated at EGP 1,974.6 millions while revenues from tourism turned out to be $6,429 in 2005 /2006. The numbers of tourists for that year 2005/2006 reached 87 millions of tourists (ESIS). The increase in investments results mainly from the increasing number of guest rooms over the last years indicating a growing trend in hotels and resorts construction as indicated on Figure 2-10.

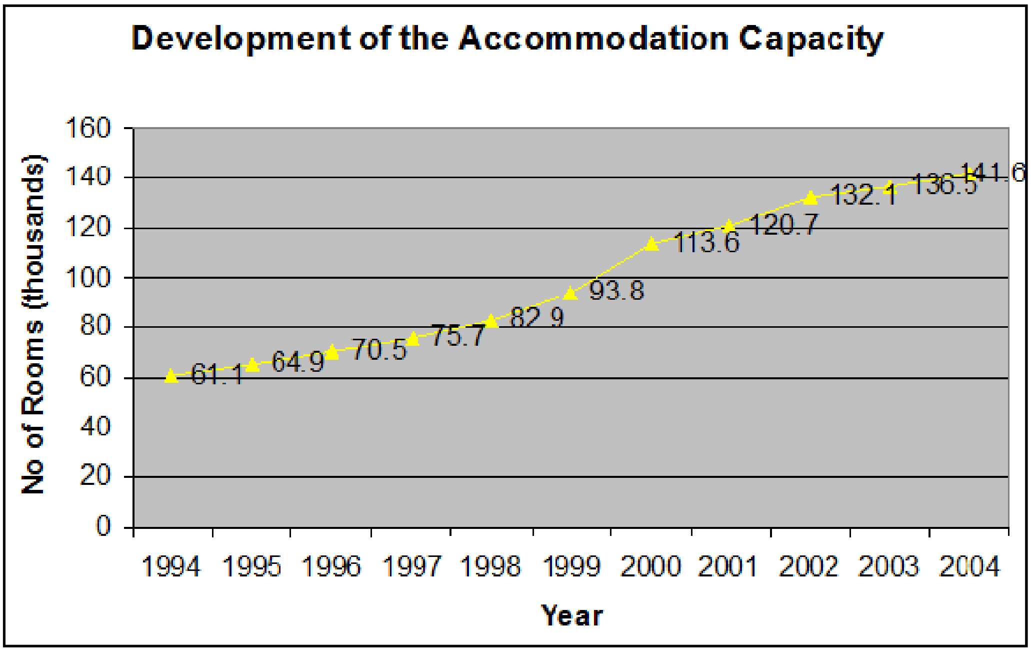

Figure 2-10: Development of accommodation capacity (MoT, 2006)

Around 90% of Egypt's tourism investment is now concentrated in the coastal resorts of southern Sinai with a product portfolio centred on dive tourism and beach holidays around the Red Sea and Gulf of Aquaba (Shackley, 1999).

2.2.2 Future Forecast

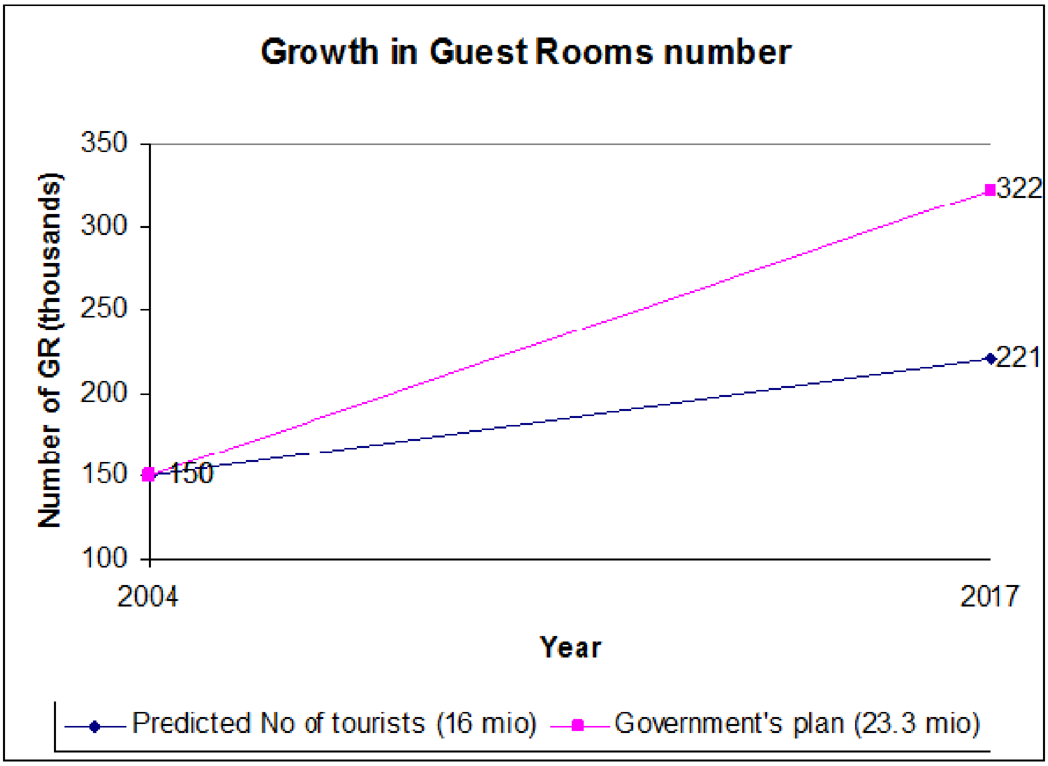

Figure 2-11: Expected growth in guest room numbers (MoT, 2006)

Egypt embarked onto implementing a programme for promoting the Egyptian tourism during the period 2006 – 2011 with the main objective of increasing its share in the world tourism market to 1.2% by 2017 which is equivalent to 16 million tourists (MoT, 2006). This leap from a tourists number of 6 million measured in 2003 will require naturally an increase in the accommodation capacity. In addition to this main objective, the government wishes also to increase job opportunities, double tourism income, attract new investors and increase urbanization.

Figure 2-11 demonstrates the expected growth in guest room numbers in terms of the growth prediction and the government's plan to attract more tourists. In 2017, the guest rooms' number should increase by at least 71,000 newly constructed rooms which is equivalent to around 220 new hotels and resorts.

In order to achieve those numbers and objectives, Egypt faces several challenges which include:

- Raising the quality of service
- Completing the development of the infrastructure
- Decrease in number of investments
- Increasing the level of education and training
- International competition

The government has defined 4 groups of directives in order to overcome these challenges (MoT, 2006):

1. Reformation of the organizational framework
2. Infrastructure development
3. Putting a strategic plan for sustainable tourism
4. Human resources

2.3 Problem and opportunity

Countries, enjoying magnificent nature either on land or under water as well as warm weather and lots of sunshine, are becoming everyday more attractive to foreign tourists, requiring more touristic developments which are, in turn, attractive to investors. Investors should not only be considering initial capital investments but also the operational and maintenance costs as well as environmental impacts which can lead to savings and improved environmental impacts on the long term. Sound decisions regarding the choice of technologies used are thus vital to achieve sustainable development as well as economical benefit.

Using today's knowledge, it is possible to conserve the limited natural resources and repair parts of the damage done for future generations. The long term objective is to gradually replace those ineffective or undesirable technologies by developing an integrated concept using environmental technologies for every single component of a project.

It is, accordingly the aim of the author to provide resort developers with a stimulating analysis on future scenarios of renewable energy application in the tourism sector which can be useful in decision making with respect to different design options and their economical and environmental impact. The thesis focuses on the early design stages where major decisions can have great implications during the hotel's life time.

2.3.1 Concerning Issues

The few studies carried out in the hotel industry field show that most hotels use energy inefficiently due to neither paying enough attention to energy requirements during the design phase nor to considering consumption criteria while selecting equipment during the procurement phase and/or due to lack in energy management during the operational phase. The problem of energy conservation in hotels and resorts is a continuous process throughout the life time of the hotel.

Among various uses of electricity, cooling contributes substantially to demand for electricity in the summer when temperatures and humidity are high. Air-conditioning is widespread not only in Egypt but in the Middle East and North Africa. Low energy prices which are strongly subsidised by the government in Egypt give no incentive to consumers neither to apply energy efficient measures nor to use renewable energy. Efficiency standards are, in general, absent in the Middle East region.

At this point, it is important to emphasise that those ambitious development plans to receive 16 million tourists by 2017 should take into consideration sustainability and renewable energy concepts. The government and developers have significant roles to play in adopting and implementing environmentally sound policies and practices to avoid the degradation of the natural heritage of Egypt for the sake of the current as well as future generations (Shaalan, 2005).

On the other hand, there is great reluctance from developers to implement environmental technologies. Sancho et al. have examined the Spanish hotel sector and found that excessive competition paralyses innovation activity of tourism enterprises. They argue that high costs for product development prevent amortisation (Walder, Weiermair, & Pérez, 2006).

2.3.2 Opportunities

Decades of technological progress have seen renewable energy technologies such as wind turbines, solar photovoltaic panels, biomass power plants and solar thermal collectors move steadily into the mainstream, making them competitive with conventional power sources. The global market for renewable energy is growing dramatically; in 2006 its turnover was US$ 38 billion, 26% higher than the previous year. This will only be enhanced by continued increases in price of fossil fuels and as the saving of carbon dioxide is given an increasing monetary value (Greenpeace, 2007).

Greenpeace (2007) claims that renewable energy technologies are real, mature and economically viable today and are ready to be deployed on a large scale, especially with their decreasing investment costs (Figure 2-12). Together with energy efficiency and decentralised energy systems, 50% of global energy can be supplied by renewables (Greenpeace, 2007).

Egypt enjoys having access to five most prominent types of renewable energy technology in Egypt: large and small scale solar thermal, photovoltaic, wind and biomass energy. Taking solar cooling as an example, the average annual total irradiation is above 2409 kWh/m_2 per annum with around 3300 hours of full sunshine and solar irradiation curve coincided with the cooling demand curve. However, these resources are generally hardly exploited in the residential and commercial sectors in Egypt.

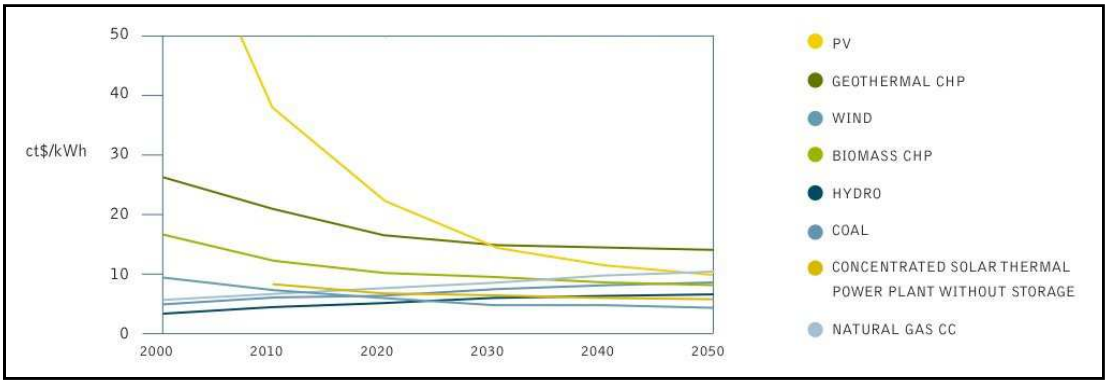

Figure 2-12: Decreasing costs of RETs (EREC & Greenpeace, 2007).

On the other hand, in 2006/07 Egypt declared the commencement with its program for nuclear power plants. Nuclear plants are not the solution. They are a fading technology with unsolved problems of nuclear waste disposal and very high environmental risks. With present consumption – only 7 % of the world energy demand is covered by nuclear energy today – the global uranium resources will not last longer than 50 years and are becoming more and more expensive. In spite of massive subsidies of several billion dollars per year, nuclear power has presently a share on the power plant market place of less than 1 %, which is a clear indicator of its obsolescence (DLR, 2005).

Moreover, with the primary direct incentive for RETs now in place Article 5 of Presidential Decree 39/2007, concerning customs tariffs, introduces a reduced custom tax of value 2% for RE equipment, components and spare parts of new and renewable energies.

In order for Egypt and the Red Sea Coast to remain a viable world-class tourism destination, the country must adopt a development strategy that will conserve the cultural and natural assets that give the region its competitive advantage. A key challenge for the tourism industry is to maintain and enhance the environmental, aesthetic, and service quality of the Red Sea Coast through public/private sector priority-setting, shared decision-making, and cooperation.

The Red Sea region enjoys the most suitable climate for solar resorts concept which has been hardly exploited up-to-date. In the next chapters, the above defined problem is addressed in details with respect to resorts energy performance in Sharm el Sheikh. The potentials and opportunities of the region are used in developing a solar design concept.

3 Review of Previous Work

This chapter presents an overview of the most relevant published work to the topic of this research. As outlined in Figure 3-1, the first section in this chapter discusses the existing literature about energy consumption in resorts worldwide and in Egypt. The second section outlines different case studies where solar design concept in hotels and resorts were adopted and the extent of applying renewable energy. The last section in this chapter reviews a selection of renewable energy technologies in terms of their technical and economic parameters that are further considered by the author in developing the proposed solar resort in Egypt.

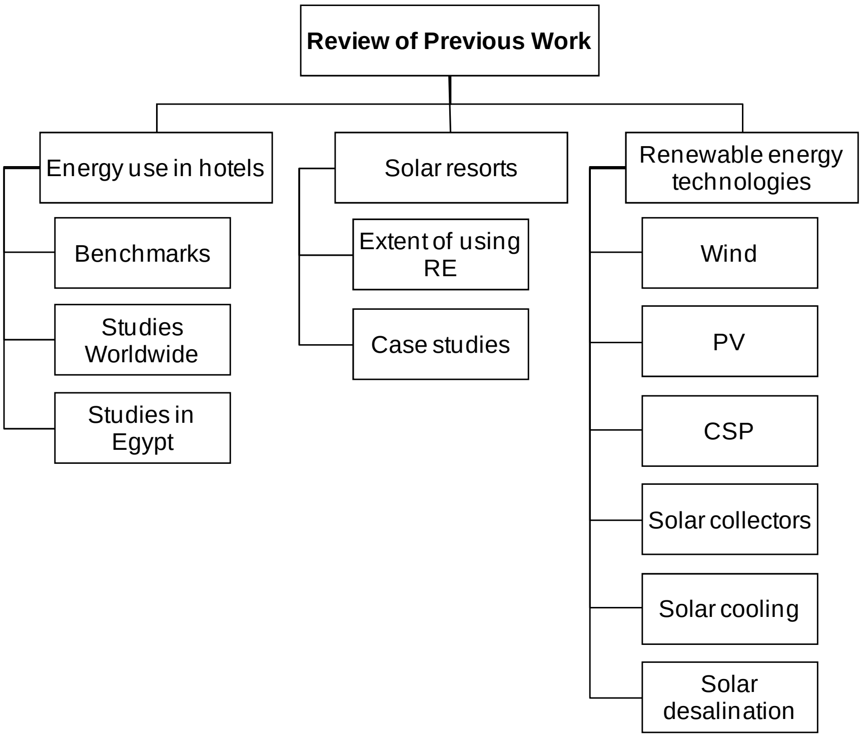

Figure 3-1: Outline of chapter 3

3.1 Energy use in hotels

Before discussing energy use in hotels, some of the relative key performance indicators (KPI) should be established. These indicators would normalise the energy performance of a hotel for variables beyond the control of hoteliers such as location, category and number of guests. It is important that KPI are expressed in a common unit. Indicators expressed in cost terms are of little benefit since they mix the changes in energy prices with rates of consumption.

The assessment of energy use performance in buildings uses an energy use intensity (EUI), which is defined as the total annual site energy use divided by the total floor area of a building (CIBSE, 1991). The most widely accepted energy benchmarks in the hotel industry are energy consumed per room, energy consumed per square meter of floor area, energy consumed by food cover, and energy consumed per guest. The last indicator considers the impact of occupancy level on energy consumption (RSSTI, 2002).

Hotels & resorts are characterised among commercial buildings by the following parameters affecting their energy consumption (RSSTI, 2002):

- Type of hotel: This means the hotel is a business, accommodation, or resort hotel type.
- Hotel classification: Hotels are classified according to the facilities they offer. This classification is expressed using the stars system.
- Hotel capacity: This can be expressed using several measures such as floor area, building volume, number of beds, or number of guest rooms or a combination of two or more of these. The most commonly used measures for capacity are the number of guest rooms and floor area.
- Hotel occupancy: This is the number of guest rooms occupied during a period of time compared with number of guest rooms available during that period.
- Laundry: There is a relationship between laundry requirements and size of the hotel. With laundries using a significant proportion of the total energy consumption (over 15% of the total energy use); it seems that a hotel with towel reuse scheme should have less energy consumption. The relationship between laundry requirements and hotel size is influences by whether a hotel has contract for outside laundry to provide laundry service for other hotels.
- Water consumption: There is a strong relationship between water consumption and energy consumption, which is attributed to the energy consumed in water desalination, pumping, heating, large pool areas, and large landscape areas.

In addition to the above, the author would add age, climate conditions and type of equipment to the above mentioned parameters which influences the rate of energy consumption.

Due to the fact that hotels and resorts are highly occupant dependant, the author has chosen to employ in her analysis the indicator energy consumed per guest-night since it takes into account the hotel dynamics such as occupancy and the extent of use of facilities which are not reflected in the other EUI forms. Similarly, water consumed would be expressed per guest-night.

Several publications exist about energy use in hotels worldwide. These include studies, benchmarks and best practice reports that are further used as a guideline in the next chapter.

3.1.1 Hotels benchmarks

Why is benchmarking important? "Benchmarking is creating a standard by which something can be measured or judged. It is a quantitative process that can help to compare an organisation's current performance against both industry and competitor standards, and to determine what needs to be improved. Benchmarks for hotels can include: The number of covers served by waiters, profit per square metre, etc. Benchmarking is an integral tool within the environmental management process that assesses environmental performance and helps to identify and prioritise areas to manage. This follows the old adage that says you can't manage what you can't measure" (Dodds, 2005).

Environmental benchmarks specifically measure environmental performance expressed in the following formats (ILBF & CI, 2005):

- Energy use (typically expressed as kWh per m^2, kWh per guest-night or CO_2 in tonnes per year);
- Water use (litres per m^2, litres or m^3 per guest-night);

- Waste production (kg per guest-night or tonnes per year):
- Amount of waste recycled;
- Use of cleaning chemicals; and
- Use of hazardous products.

KPI and environmental benchmark are in effect the same process though the objective might be different. Environmental benchmark is mainly used to achieve a sustainable performance and achieve eco-efficiency by those seeking environmental certification and compliance to national, regional and/or international legislation while KPI might be used for the purpose of operational cost reduction only or for evaluating both environmental and cost performance.

Evaluation	**Excellent**	**Satisfactory**	**High**	**Excessive**
Temperate				
Electricity	<135	135-145	145-170	>170
Other energy	<150	150-200	200-240	>240
Total	<285	285-345	345-410	>410
Mediterranean				
Electricity	<140	140-150	150-175	>175
Other energy	<120	120-140	140-170	>170
Total	<260	270-290	290-345	>345
Tropical				
Electricity	<190	190-220	220-250	>250
Other energy	<80	80-100	100-120	>120
Total	<270	270-320	320-370	>370

Table 3-1: Benchmarks for energy consumption for luxury fully serviced hotels in kWh/m^2 (Dodds, 2005; ILBF & CI, 2005)

Evaluation	**Excellent**	**Satisfactory**	**High**	**Excessive**
Temperate	<0.50	0.50-0.56	0.56-0.90	>0.90
Mediterranean	<0.60	0.60-0.75	0.75-1.10	>1.10
Tropical	<0.90	0.90-1.00	1.00-1.40	>1.40

Table 3-2: Benchmarks for water consumption for luxury fully serviced hotels in m^3/guest night (Dodds, 2005; ILBF & CI, 2005)

The WWF organisation in the UK carried out a benchmark study on the basis of data available from approximately 1,000 hotels of differing standards from around the world (ILBF & CI, 2005). Table 3-1 & Table 3-2 show the benchmark results of energy and water consumption respectively for hotels classified as luxurious in different climate zones.

Hotels can easily benchmark their own performance, target future improvements and measure progress. For example, benchmarking energy and water consumptions can instigate the hotelier in introducing energy efficiency measure. This is an essential step before stepping into applying renewable energy which can result in smaller capacities and, thus, lower capital investment costs. Benchmarks can also be used during the planning and design stages in evaluating the calculated figures and judging whether the project would be efficient or would exceed the normalised consumption figures requiring reengineering of the design.

3.1.2 Studies of energy use worldwide

Energy use in hotels and resorts covers not only electricity based equipment but also thermal systems such as HVAC (heating, ventilation and air conditioning) systems and in some cases water production and treatment as well. The highest consumers would vary from one hotel to another depending on its location, type and facilities. However, studies show that HVAC systems could be one of the highest energy consumers in a hotel. In fact, there are numerous researches which have shown that the source of approximately 50% of the energy consumption in hotels is due to thermal comfort (Alujević, 2006). The European research project REST (Renewable Energy and Sustainable Tourism) indicates a total energy share of 69% for heating, domestic hot water (DHW) and air-conditioning (Figure 3-2) while another study shows that the heating, air-conditioning and DHW count all together for 61% of energy consumption as in indicated in Figure 3-3.

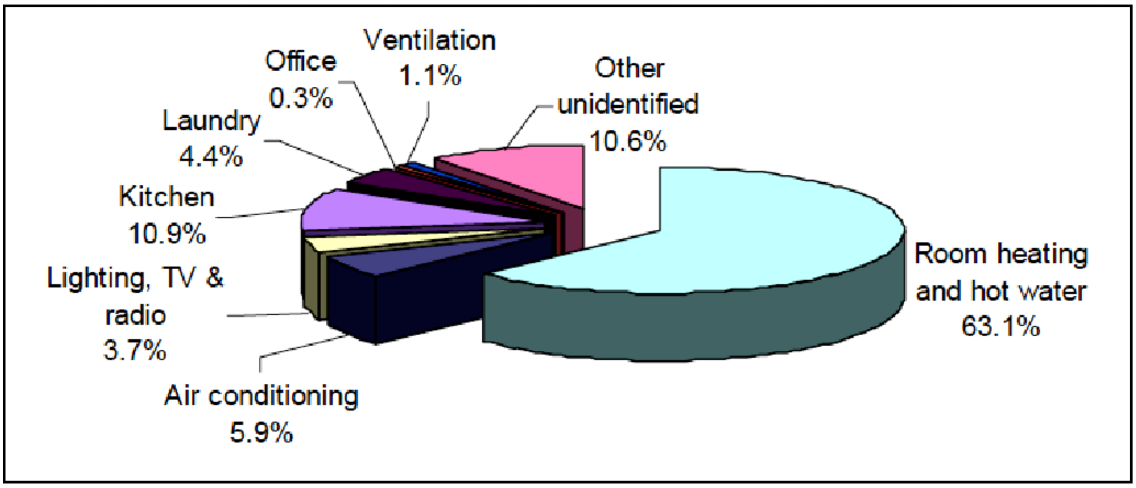

Figure 3-2: Energy consumption by end-users in a hotel (Alujević, 2006; REST)

In a study carried out on energy use in 16 hotels in Hong Kong, the averaged percentage breakdown of the total electrical energy as depicted on Figure 3-4 shows that air conditioning dominates the total electricity use which is mainly due to the sub-tropical climate (Shiming & Burnett, 2002).

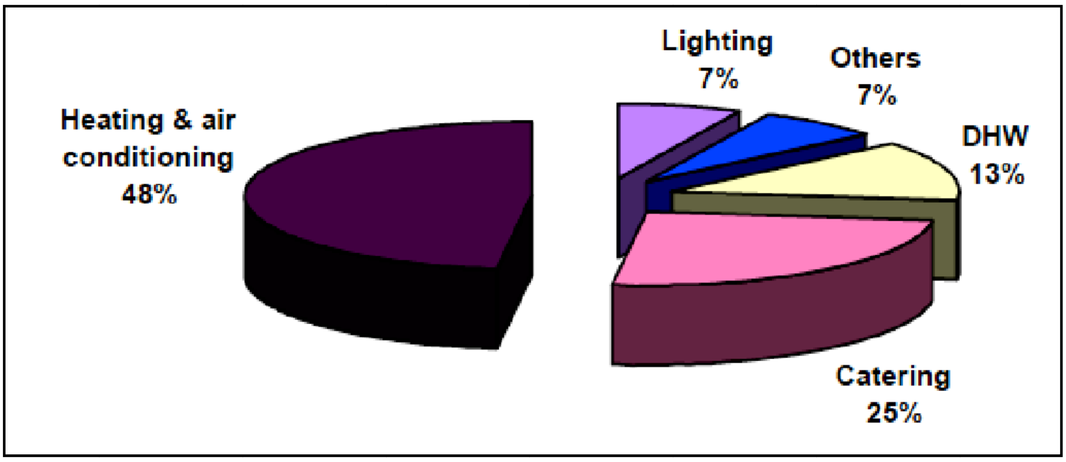

Figure 3-3: Energy consumption by end-users in a hotel (Alujević, 2006; CADDET, 1997)

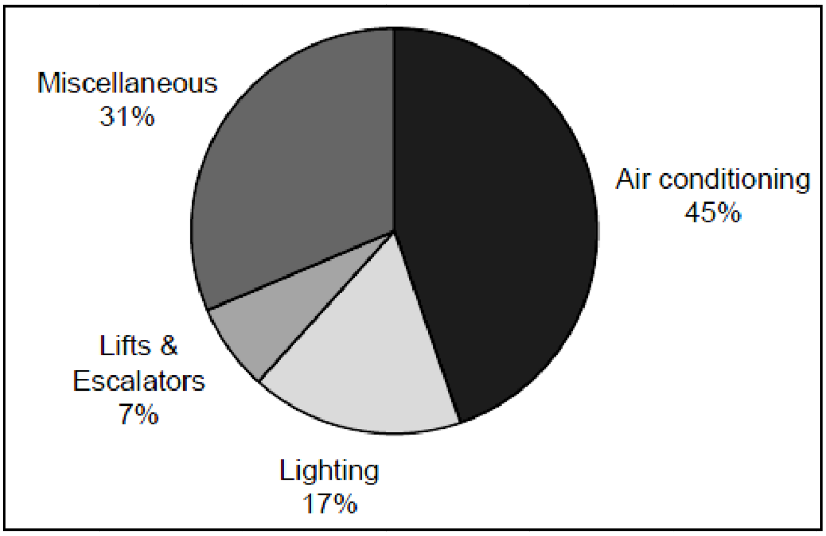

Figure 3-4: The average percentage breakdown of the total electricity in the 16 hotels (Shiming & Burnett, 2002)

Over the last decade the growth of electricity consumption in many hotels has been in the range of 25-30%. This increase may be attributed to the growing number of facilities, more demanding standards of accommodation as well as development of the operating equipment. On the other hand, the shift to more efficient equipment and lighting has recently been observed in many world regions. In spite of this, it is estimated that the energy demand may further increase by 10-25% in the coming years (Alujević, 2006; Paulina Bohdanowicz, 2003).

Table 3-3 & Table 3-5 show the consumptions of some hotels investigated worldwide in a study carried out by Paulina Bohdanowicz & Martinac (2007). The electricity consumption, expressed in kWh per guest-night, seems to lie within the same range except for Cyprus and Majorca who seem to have better energy performance. Although, it is not mentioned in the study but the author deduces that Cyprus and Majorca apply solar energy extensively which accounts for the lower consumption.

Country (data for the year)	Average energy use, kWh/guest-night
Europe (1990s)	55.5
New Zealand (1999)	43.1
Zanzibar (2000)	71.1
Cyprus (2001)	24.2
Majorca (2001)	14.2

Table 3-3: Average energy consumption for hotels worldwide (Paulina Bohdanowicz & Martinac, 2007)

On the other hand, Table 3-4 summarises the results of another study carried out on energy consumptions in Mediterranean country hotels showing excessive electricity consumption when compared to the WWF benchmark values mentioned previously in Table 3-1.

	Greece	Cyprus	Portugal	Italy
Energy consumption in kWh/m^2	72 - 519	103 - 370	99 – 444.6	249 - 436
Average energy consumption in kWh/m^2	289.9	272.6	296.4	364.4

Table 3-4: Average yearly energy use intensity for hotel buildings in kWh/m^2 (Paulina Bohdanowicz, 2003; P. Bohdanowicz & Martinac, 2003; CHOSE, 2001)

In her thesis, Alujević (2006) carried out an energy audit scheme on hotels located on the Adriatic coast in Croatia with a special focus on HVAC systems. The results were presented in terms of kWh/m^2. The electricity consumption (used for lighting, TV, elevators, kitchen, laundry and HVAC systems) varied in case of non-seasonal five stars hotels between 95 and 180 kWh/m^2 (Figure 3-5). Thus, the energy performance varies between satisfactory to excessive based on the WWF benchmark values.

On comparing the indicated water consumptions in Table 3-5 with the benchmark values mentioned in the previous section in Table 3-2, Germany, Jamaica and Sweden have an excellent water consumption, while Spain's level varies from high to excellent and Zanzibar has a satisfactory performance.

Other studies estimated that – depending on the hotel standard – guests typically use between 90 and 150 litres of water per night (THERMIE, 1994). However, a recent report published by one chain provides an average figure of 440 litres/guest-night (SAS, 2002), while another chain reports an average figure of 224 litres/guest-night (P. Bohdanowicz & Martinac, 2003; Scandic, 2000).

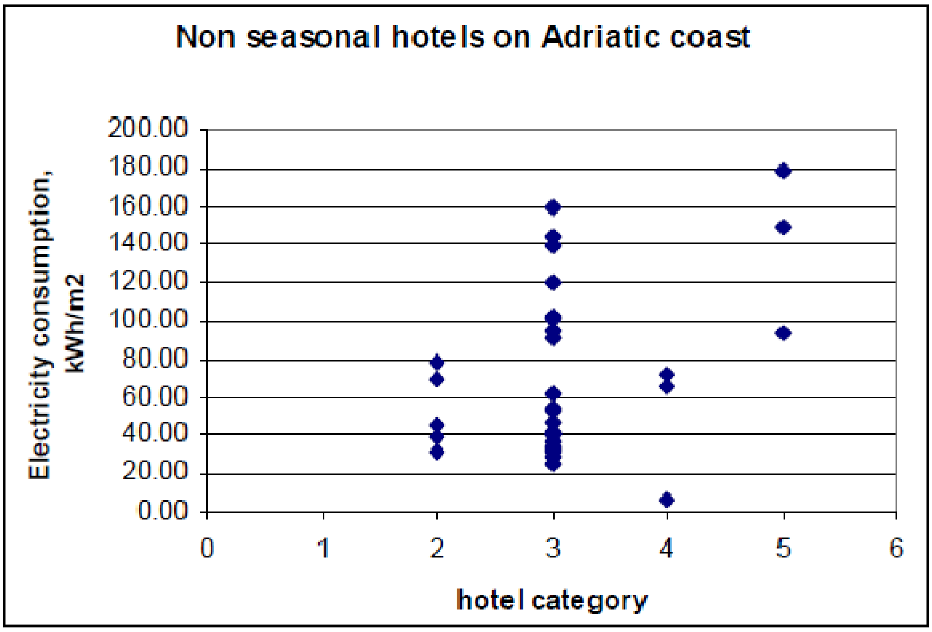

Figure 3-5: Electricity consumption for non seasonal hotels on the Adriatic coast by hotel category (Alujević, 2006)

Country (data for the year)	**Average water use, litre/guest-night**
Germany (1990s)	342
Jamaica (1999)	275
Spain (2000)	440 -880
Zanzibar (2000)	930.9
Sweden (2002)	314

Table 3-5: Average water consumption for hotels worldwide (Paulina Bohdanowicz & Martinac, 2007)

With regards to CO_2 emissions, only a few studies discussed the amount of emissions produced by hotels. Depending on the source of energy (hydro, wind, nuclear, oil, or coal based) hotels can be responsible for the annual generation of up to 160 kg of carbon dioxide per square meter of area, which is equivalent to 10 tCO_2 per bedroom (EEO, 1993).

3.1.3 Studies of energy use in Egypt

Responding to the increasing demand for leisure tourism on the Red Sea, the Egyptian Tourism Development Authority (TDA) with funding from the US Agency for International Development (USAID) introduced the 'Best practices for Tourism Centre Development along the Red Sea Coast' in 1998. Five years later, TDA, through the Red Sea Sustainable Tourism Initiative, (RSSTI) introduced the series of best practices covering energy management and water & sanitation. The Best Practice for Energy Management covers considerations for improving the energy efficiency of buildings and focuses on the efficiencies of air conditioning, pumps and lighting but does not expose any information with regards to neither consumption rates nor installation and operation costs.

Although TDA mentions the concept of benchmarking in its Best Practice guide, yet there are no figures available. TDA may consider developing a benchmarking system for the hotels on the Red Sea Coast (RSSTI, 2002).

Furthermore, there are hardly any academic researches that have been conducted on resorts in Egypt and their KPI which leads to lack in data about energy consumption and its utilisation.

3.2 Solar resorts

A solar resort is a tourism accommodation facility that enables sustainable tourism through the establishment of self sufficient hotel facilities and sustainable natural resources. It would ideally meet the following criteria:

1. conserves the surrounding environment, both natural and cultural;
2. has minimal impact on the natural surroundings during construction;
3. fits into its specific physical and cultural contexts through careful attention to form, landscaping and colour;
4. uses alternative and sustainable means of water acquisition and reduces water consumption;
5. provides careful handling and disposal of solid waste and sewage;
6. meets its energy needs through passive design and renewable energy;
7. endeavours to work together with the local community;
8. offers interpretative programs to educate both its employees and tourists about the surrounding natural and cultural environments; and
9. contributes to sustainable local development through research programs.

The main elements of a solar resort are outlined on the diagram in Figure 3-6. Passive energy is mainly achieved through solar architectural which integrates passively and/or actively uses solar energy to prevent heat gain and/or loss (Figure 3-7). Solar architecture has been extensively discussed in the literature with respect to methodology and impact. For example, in their guide book ILBF & CI (2005) provide a practical and accessible resource for anyone involved in the process of planning or developing hotel accommodation to help them ensure that the finished building will be more environmentally and sociable responsible.

The implementation of energy efficiency measures is well studied (Dalton, Lockington, & Baldock, 2008) and is not further discussed in this thesis. It is, therefore, not within the scope of this thesis to expand on this topic. The results of previous researches are taken as sound assumptions and used in the development of the solar design alternatives in chapter 5. The thesis will rather focus on the part of active energy discussing and analysing different renewable energy and its applications.

Water heating accounts, on average, for approximately 12% of the total energy costs (20% of energy use) in a hotel; thus, solar water heaters can lower fuel and electricity bills (UNEPTIE, 2003).

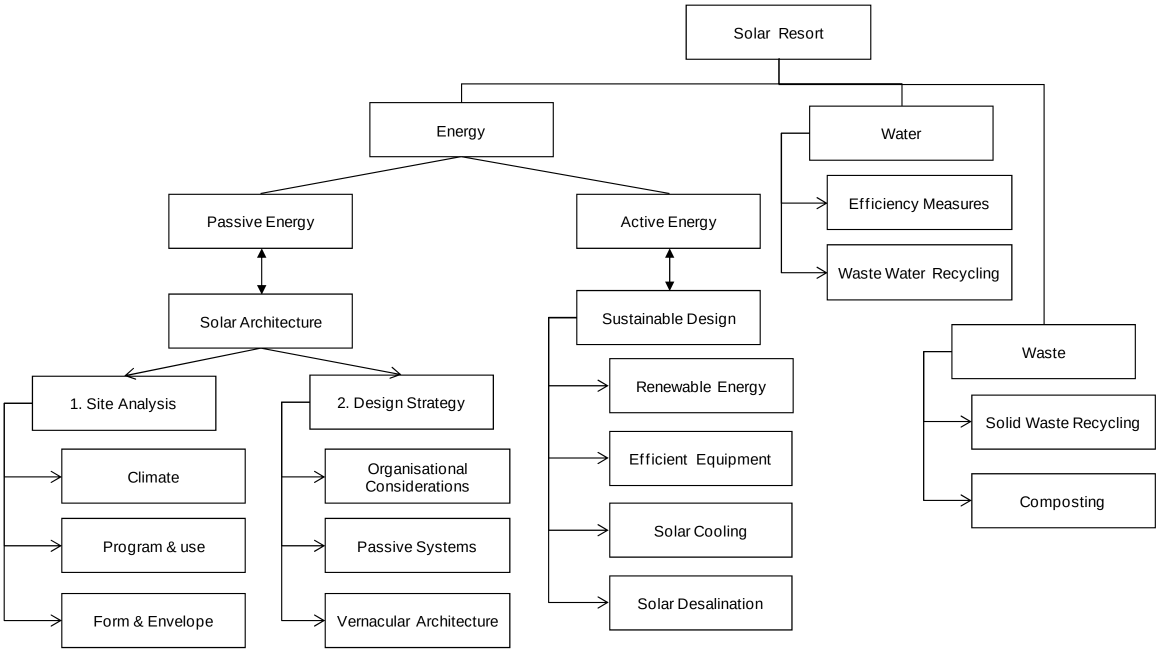

Figure 3-6: Elements of solar resorts

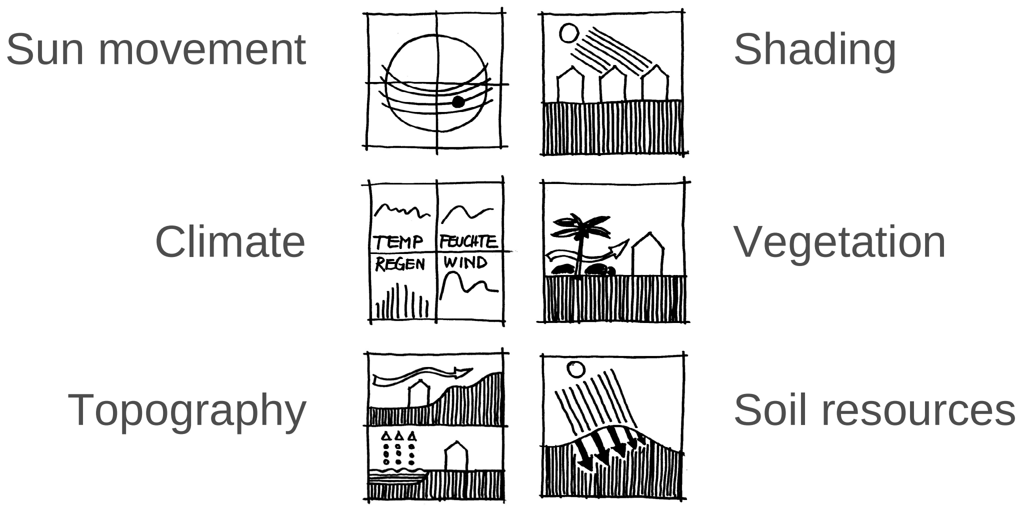

Figure 3-7: Solar Architecture Elements

Without renewable energy, sustainability cannot be fulfilled. It is described as being regenerative, abundant, inexhaustible and clean. Sustainable energy is accordingly defined as the energy which is replenishable within a human lifetime and which causes no long-term damages to the environment. Solar energy, wind energy, geothermal energy, hydropower and biomass are all self-sustaining energy resources.

Hotel units represent a particular category of energy consumers of the tertiary sector, where energy planning may provide significant advantages. It should be noted that among the candidate solutions, there are technologies that can be implemented to the exclusion of other options and technologies complementing one another (Mavrotas, et al., 2003). For example, besides the traditional energy supply options, it is possible to implement combined heat and power (CHP) systems, eventually with an absorption chiller for air conditioning, while active solar systems and photovoltaic may also be used to meet a significant part of the total energy demand.

Besides energy, water and waste issues are nevertheless considered as integral elements in establishing a solar resort. However, they are not addressed within the scope of this study as mentioned earlier in chapter 1.

3.2.1 Use of renewable energy in the hotel sector

This section investigates the extent of using renewable energy in the hotel industry. Considering that hotels are often located in places with an abundance of solar, wind and/or other renewable, it is surprising that these resources remain largely unexploited. The Hawaiian Islands provide a showcase example of an attractive and well-visited travel destination blessed with abundant supplies of practically every renewable energy resource imaginable. Despite this, more than 955 of the energy use in the State of Hawai'i is still fossil-fuel based. Many similar examples can be found worldwide (Paulina Bohdanowicz, Churie-Kallhauge, Martinac, & Rezachek, 2001).

Only two comprehensive feasibility case studies appear in the literature examining the feasibility of renewable energy supply (RES) in stand-alone power supply (SPS) tourist accommodation. Bakos & Soursos (2002) reported a successful PV set-up for a small-scale tourist operation (up to 10 beds) in Greece, concluding that the configuration was economically viable. Bechrakis, McKeogh, & Gallagher (2006) also demonstrated the viability of a proposed wind/hydrogen system for a small-scale hotel in Greece. Whilst other case studies considering functional stand-alone RES operations have been reported, they do not conduct rigorous feasibility analysis (Dalton, et al., 2008).

Mavrotas, et al. (2003) modelled an existing luxury hotel located by the seashore, 25 km from the centre of Athens, which consists of three separate complexes with 600 rooms in addition to 70 independent bungalows. The hotel's energy requirements are classified into the following uses: space heating, water heating, laundry, cooking, air conditioning, lighting and other electric uses and were met basically through liquid petroleum gas (LPG) and electricity from the grid. The objective was to identify which efficient solutions and combinations can be used. The candidate investment options included energy supply options, like combined heat power units, absorption chillers, solar systems, and energy efficient measures such as economy lamps and double glazing. It was observed that none of the efficient solutions comprise solar systems. This was explained by their higher annualized cost compared to the cost of the competitive energy forms (LPG & grid electricity). On the other hand, the proposed energy efficient measures are participating in all the efficient solutions (Mavrotas, et al., 2003).

Dalton, et al. (2008) indicate that studies have been conducted on small and medium-sized SPS operations, mostly ''ecotourism'' type, while large mainstream tourist resorts (over 100 beds) have not been extensively investigated. Large-scale accommodation operations have unique operational characteristics in comparison to their smaller counterparts, demanding larger load capacity due to increased air-conditioning requirements and more expansive comfort facilities.

Accordingly, due to the limited number of RES case studies in tourist operations and the absence of studies for large resorts, which require facilities with a higher degree of comfort such as air-conditioning, it is not possible to establish with confidence the viability of RES in this industry (Dalton, et al., 2008).

On the other hand, studies of successful RES installations have been carried out on many non-tourist enterprises and are split into two configuration categories (Dalton, et al., 2008):

1. RES for complete autonomous supply, such as photovoltaic (PV-only) configurations, wind energy conversion systems (WECS-only) and combinations of PV/WECS.
2. RES in 'hybrid' combinations with diesel generator, such as PV hybrids, WECS hybrids, PV/WECS hybrids and large-scale PV/WECS hybrids.

It is generally observed that the attitudes towards the use of renewable energy are still commonly negative on the basis of being expensive and unreliable compared to fossil and/or nuclear based resources. In his research, Dalton et al. also indicates that there is reluctance by Australian tourist operators in adopting RES systems. Studies reveal that a perception exists within the tourist sector that RES is incapable of supplying sufficient power (Dalton, Lockington, & Baldock, 2007; Lowe & Lloyd, 2001), is unreliable (Dalton, et al., 2007; Lloyd, 2000) and, most importantly, is not economically viable (Dalton, et al., 2007; Deda, 2000; Lloyd, 2000) and have extensive payback times (Turner, 1999). Few case studies have examined whether these perceptions are valid, especially with regard to large-scale SPS-dependent tourist operations.

In a statistical sample of 32 Greek hotels spread out with equivalent statistical frequencies over the country's regions and over the various hotel categories only two units have been found using RES technologies, other than solar active -solar collectors- (Michaelis Karagiorgas et al., 2006) (Figure 3-8).

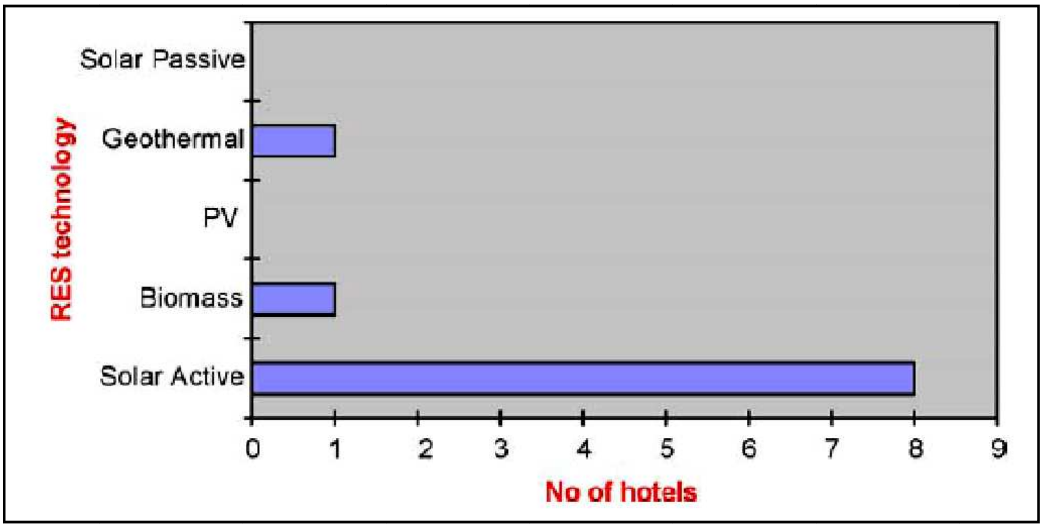

Figure 3-8: Penetration degree of RES in a 32-hotel statistical sample in Greece (M. Karagiorgas & Tsoutsos, 2003)

Furthermore, a survey was carried out on 200 hotels in five regions located in the Mediterranean area in order to investigate whether RES application in the hotel industry has reached a high level of technological maturity and a reasonable degree of economic liability (Michaelis Karagiorgas, et al., 2006). Figure 3-9 shows that the majority of the opinions ranked the importance of introducing RES in a hotel from low to medium while 72% of the opinions see no possibility of investing in RES in the next 5 years (Figure 3-10). Figure 3-11 indicates that the majority of the hotels personnel surveyed have very low to low knowledge of RES subjects.

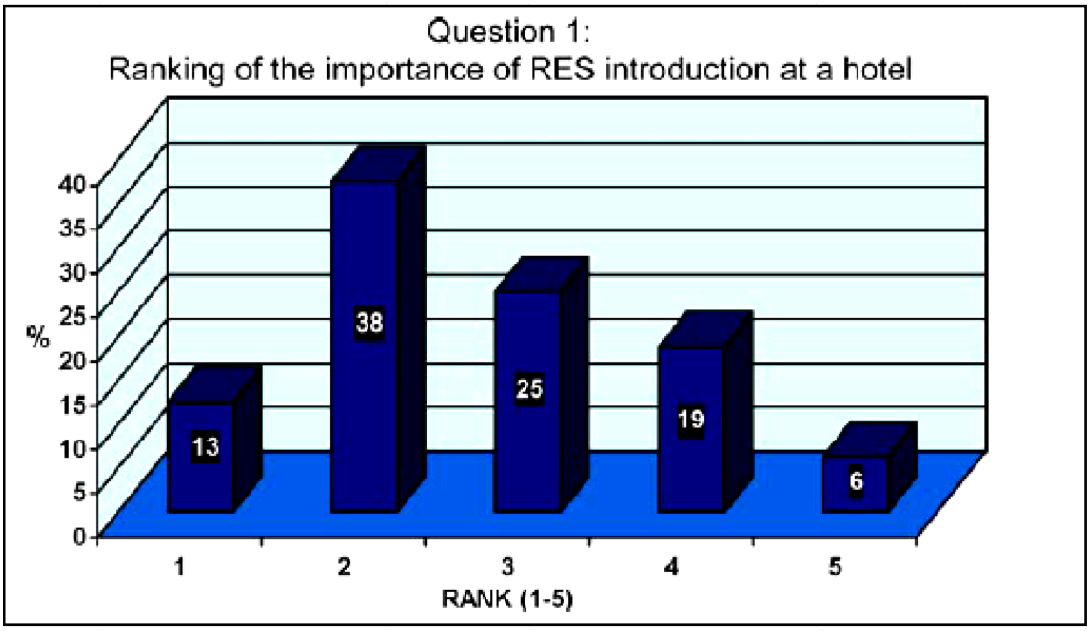

Figure 3-9: Performance of RES, when the hotel personnel of 200 hotels in the EU is asked (Michaelis Karagiorgas, et al., 2006)

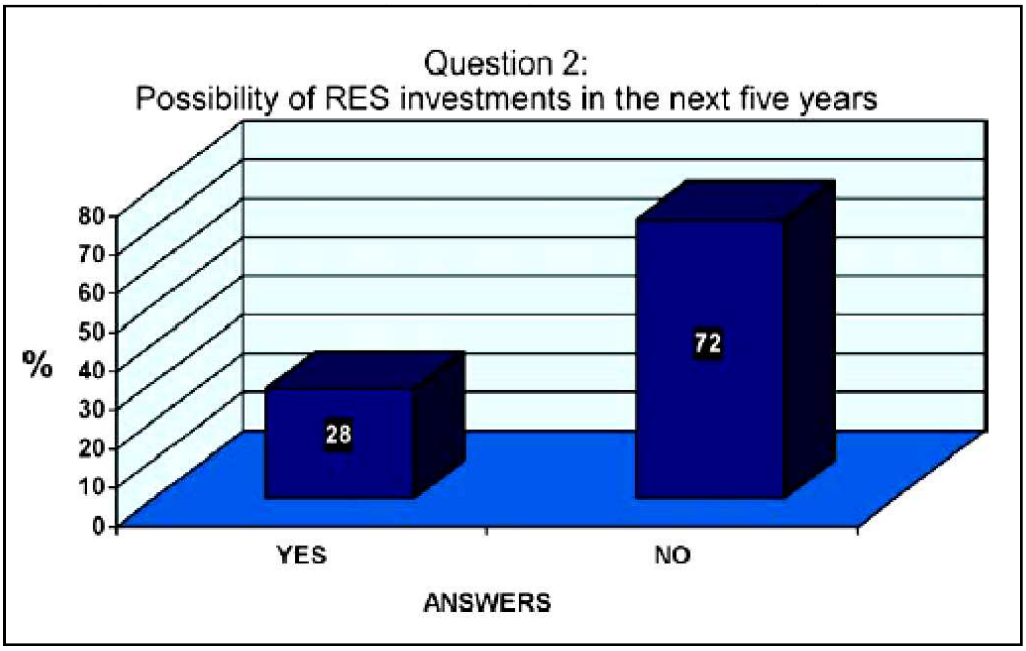

Figure 3-10: Investment opportunities for RET in 200 hotels in the EU (Michaelis Karagiorgas, et al., 2006)

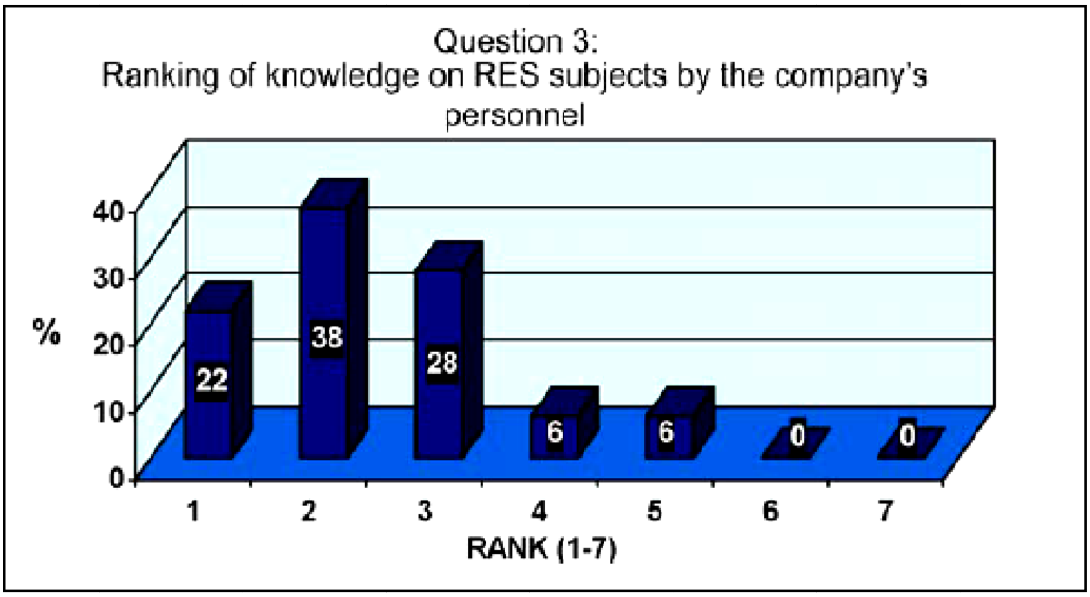

Figure 3-11: Level of knowledge of RET by the personnel of 200 hotels in the EU (Michaelis Karagiorgas, et al., 2006)

The survey also indicates that in those five regions, solar thermal collectors and geothermal energy are the strong candidates for future expansions in the hotel sector. Solar PV energy is rather important, while biomass energy presents a poor profile. It is very surprising that solar passive energy, which should be the strongest product to penetrate the hotel market, is very low in inquiries, despite the strong promotion during events (Michaelis Karagiorgas, et al., 2006).

It can be concluded that there is an extremely low degree of RES penetration in the hotel industry. Solar thermal collectors used for supplying heating or hot water might be an exception where it is widely used in the hotel industry in southern Europe.

The specific operational characteristics of the tourism accommodation sector, such as 24-h/7day operation, comfort provision and low tolerance for failure, necessitates a separate assessment of RES viability for this sector, rather than relying on similar assessments from other commercial sectors.

3.2.2 Case studies of solar resorts

The published literature illustrates a lot of case studies with respect to energy efficiency measures which achieved the assumed energy savings while very few case studies illustrate the use of RETs in hotels. The Renewable Energy Tourism Initiative best practices in the accommodation sector illustrates the experiences, insights, and resources provided by several hotels and resorts (RETI, 2008). The following are a selection of published case studies which show the extent and success of applying RETs in hotels worldwide:

- **Case study 1, *Solar hot water:*** As part of its commitment to supporting renewable energies, Accor carried out a project called “100 solar hotels”. The goal was to equip about a hundred of its hotels in France, Morocco, Brazil, China and Australia with solar collectors to produce hot domestic water covering on average 40 to 60% of the needs each year. The average price was around 800 €/m² price depending on the hotel’s location. The energy savings vary depending on sunshine levels: for example, in Lyon, the productivity was about 570 kWh/m²/year, making an annual saving of 28 €/sq. meter. The payback time is between 10 and 15 years, even after taking into account the 50% subsidy granted by the French Agency for environment and energy, ADEME, for those installations in France (ACCOR, 2010).

- **Case study 2, *WECS:*** The Couran Cove Resort is a five stars resort with 567 units located on south Stradbroke Island in southern Queensland, Australia. The facility offers the typical amenities for a resort type of this category. The business objective was to achieve sustainable operations while maintaining cost-efficiency. The average daily electricity consumption at the facility is ca. 4,200 kWh in addition to 20 GJ/day (5,560 kWh/day) of liquid petroleum gas, LPG, used for heating. Three alternatives were considered: the first alternative was based on WECS combined with LPG generators equipped with a heat recovery system; the second alternative was based on grid electricity; and the third alternative was based on diesel generators with heat recovery (Paulina Bohdanowicz, et al., 2001). It was reported that the first option yielded the least life cycle cost -capital, operational and maintenance costs- and significant reduction in CO_2 emissions and fossil fuel consumption.
- **Case study 3, *Solar heating/cooling:*** The main goal of the project, Hotel Belroy Palace, located in Alicate Spain was to install a solar collector system for space cooling, heating and for domestic hot water for the hotel building. The new solar system consists of 328 m^2 of high efficient solar collectors and a heat storage volume of 36 m^3. During the summer time the produced hot water is used for cooling using LiBr-H_2O absorption chiller and providing domestic hot water. In winter time heat is used for space heating and domestic hot water. After three years of system operation energy savings is 90% of the energy required for hot domestic water, 80% of energy required for space heating in winter and 60% of cooling energy during the summer time. These savings corresponds to a reduction of 61 tons per year in fuel consumption and a reduction of 110 MWh per year in the electricity used for operating the chiller compressors (Alujević, 2006; IMPIVA, 1994).
- **Case study 4, *Solar Power:*** A one megawatt solar PV system is installed at Xanterra Parks & Resorts, one of the largest non-utility systems in the U.S (RETI, 2008). No further details were available.
- **Case study 5, *WECS:*** At Paradise Bay located on one of the Caribbean Islands, an 80 kilowatt- windmill is installed, accounting for 150 percent of the property's energy needs. The cost per kWh for energy produced by the windmill is US$0.258, taking into account write-offs, product life, maintenance costs, and profits from surplus energy supplied to the local utility. Compared to the electricity company's cost of US$0.331, this represents a savings of 22 percent (RETI, 2008).

Reviewing most of the literature and published case studies on renewable energy and sustainability, the following can be noted:

- The majority of resorts and hotels considered are of small capacities with less than 100 beds.
- The most widespread and successful RET is solar thermal collectors used for heating and hot water production.
- Very few cases illustrate the use of PV and WECS.
- Lack of adequate information about the return on investment or other critical economical metrics which allow rigorous comparison of renewable energy options. It should also be

pointed out that many of those case studies were partly subsidised or funded by an organisation and/or received special incentives or tax exemptions in order to encourage the use of renewable energy.

Generally, it is observed that supported by a backup system, RET can be successfully technically applied, yet remains the question whether all of those case studies represent the reality from the economic point of view.

3.3 Renewable energy technologies

The major limitation of RETs lies in the intermittent and site-specific nature of the energy source. Solar cells, for example, generate electricity only when light is available, and wind generators operate only when there is sufficient wind (Fries, 2000). Nevertheless, this limitation can be overcome by using a combined energy mix depending on the specifics of each location. Different forms of energy storages can also be used to provide electricity or heat to overcome any shortages. The most common combination form of energy mixes are solar, wind and/or biomass.

RETs were examined in 50 case studies and have shown an interesting level of cost effectiveness. This effect is highly important when subsidies of local governments are taken in account. The shortest payback period refers to the solar thermal varying from 1.7 years in Greece up to 19 years in France. The payback period for Solar PV varies from 6 years in Spain up to 43 years in Greece (Michaelis Karagiorgas, et al., 2006):

The following RETs play an important role in achieving sustainable tourism as they can be installed on individual premises where they supply energy to a particular project rather than a network and are directly financed by that project:

- Power supply such as PV, Concentrated Solar Power (CSP) and WECS.
- Solar cooling
- Solar desalination

The author has excluded technologies related to hydro, biomass and geothermal energy due to the fact that they are either scarce or not easily accessible in the Red Sea region, the focus area of this study.

Internet research showed that very few RET companies exist on the Egypt market and that all products offered are imported with the exception of solar thermal collectors which are also locally produced. Worldwide market prices were considered in this thesis since inquires for local quotations and prices were met with either no response or incomplete offers. Based on the author's experience in project procurement in Egypt, a factor of 15% from the net ex-work price would cover transportation and installation costs.

The author used two software as supporting tools in evaluating some of the RETs and validating the results of the developed model. The RETScreen Clean Energy Project Analysis software can be used worldwide to evaluate energy production, and savings, costs, emission reductions, financial viability and risk for some types of RE and energy efficient technologies. The software also includes product, project, hydrology and climate databases (NRCAN). The HOMER Energy software, the micro-power optimization model, can be used in evaluating designs of both off-grid and grid-connected power systems for a variety of RE applications (NREL, 2005).

3.3.1 Wind Energy Conversion Systems

WECS converts energy in the wind into electrical energy, or into mechanical energy for pumping water or grinding grain. The most common wind turbines in operation today have two or three blades revolving around a horizontal axis. These “horizontal axis wind turbines” also include a gearbox and generator, a tower, and other supporting mechanical and electrical equipment. Wind turbines are rated by their maximum power output in kW or MW. For commercial, utility-sized projects, the most common turbines currently sold are in the range of 600–1,000 kW. These are large enough to supply electricity to 600–1,000 average modern homes (Fries, 2000).

Of all the new renewable energy technologies, generating clean electricity from the wind has made the most significant commercial progress. A reduction in the levels of carbon dioxide being emitted into the global atmosphere is the most important environmental benefit from wind power generation. At the same time, modern wind technology has an extremely good energy balance. The CO_2 emissions related to the manufacture, installation and servicing over the average 20 year lifecycle of a wind turbine are paid off after the first three to six months of operation (GWEC, 2006).

The global market for wind power has been expanding faster than any other source of renewable energy. From just 4,800 MW in 1995, the world total has multiplied more than twelve-fold exceeding 59,000 MW at the end of 2005 (GWEC, 2006).

3.3.1.1 Capacities and costs

Most commercial wind turbines operating today are at sites with average wind speeds greater than six metres per second, although some commercial sites have average wind speeds as low as 5 m/s. For example, a 1 MW turbine can produce enough electricity for up to 650 households, depending on its location. Overall, wind turbines have a design lifetime of 20-25 years (GWEC, 2006). For off-grid and mini-grid applications, wind generators can be combined with diesel generators or other energy sources, as well as batteries or other storage device

Most of the commercial-scale turbines installed today are 2 MW in size and cost roughly $3.5 Million installed. Wind turbines have significant economies of scale. Smaller farm or residential scale turbines cost less overall, but are more expensive per kilowatt of energy producing capacity. Wind turbines under 100 kilowatts cost roughly $3,000 to $5,000 (equiv. €2150 to €3570) per kilowatt of capacity (Windustry). Wind power costs from previous years might justify a figure of ca. $1,200/kW (860 €/kW), but in 2004 wind power costs rose, some said to more typically $1,300/kW (930 €/kW), due to higher steel prices from high global demand for steel. Canada, for example reported a price of $1,500/kW (1070 €/kW) in 2004 (ERC, 2006).

Data analysed in ‘The Wind Energy Operations & maintenance Report’ suggest that average operations and maintenance (O&M) costs run at approximately $0.027/kWh or €0.019/kWh per kWh (Muckosy, 2010).

3.3.1.2 Constrains & disadvantages

The construction and operation of wind power often raises issues of visual impact, noise and the effect on local wildlife such as birds. These issues should be addressed through an environmental impact assessment for each project depending on its location, project site conditions and surrounding environment.

RETs are still being developed and may have some technical limitations which, however, can be overcome with further research and development.

3.3.2 Photovoltaic

"For years, solar generated electricity has been often dismissed as too costly, but recently the cost is consistently coming down versus the rising cost of conventional electricity. Advances in solar cell technology, conversion efficiency and system installation is allowing PV to achieve cost structures that may be competitive with other peaking power sources. The solar industry has achieved a total installed capacity of approximately 10 GW of PV systems around the globe" (Sunpower, 2008).

PV can be either mounted on roof tops and/or on the ground level depending on the space available. The following factors are main criteria of any solar PV system which should be taken into consideration during design development:

1. Panel type; at the present time, most commercial photovoltaic cells are manufactured from silicon, the same material from which sand is made. The four general types of silicon photovoltaic cells are: Single-crystal silicon, Polycrystalline silicon (also known as multi-crystalline silicon), Ribbon silicon and Amorphous silicon (also known as thin film silicon).
2. Panel efficiency; the efficiency depends on the type of panel. Single-crystal silicon panels have the higher efficiencies exceeding 20% while thin film panels have the lowest efficiencies exceeding 11% (AMECO).
3. Location; the surrounding temperature plays an important role in the selection of panel type since efficiency decrease with the increase in temperature. For example, thin films are best suited for hot areas such as the Middle East, tropical and sub tropical regions.

3.3.2.1 Capacities and costs

The economies of scale inherent in utility-scale solar systems are similar to those found with other power options, but PV has the benefit of being completely modular – PV works at a 2 kilowatt residential scale, at a 2 megawatt commercial scale or at a 250 megawatt utility scale. The size of a typical PV system varies from 50 W–1 kW for stand-alone systems with battery storage; from 500 W–5 kW for roof-top residential grid-connected systems; and from 10 kW–1 MW for larger building-integrated and grid-connected systems.

The module cost represents around 50 - 60% of the total installed cost of a solar energy system. Therefore, the solar module price is the key element in the total price of an installed solar system (Solarbuzz, 2010). The recent market survey carried out by Solarbuzz (2010) and published in November 2010 indicates that there are now 595 solar module prices below $4.00 per watt (€2.84 per watt) representing 44.8% of the total survey. The lowest retail price for a multi-crystalline silicon solar module is $1.80 per watt (€1.28 per watt) from a US retailer. The lowest retail price for a mono-crystalline silicon module is also $2.27 per watt (€1.61 per watt), from a German retailer. The lowest thin film module price is at $1.37 per watt (€0.97 per watt) from a United States-based retailer. These prices are based upon the purchase of a single solar module and prices are exclusive of sales taxes.

PV modules may operate for up to 30 years and are generally sold with 10–20 year manufacturer warranties.

3.3.2.2 Constrains & disadvantages

Solar electricity is not produced at night and is much reduced in cloudy conditions. Therefore, storage or a hybrid system would be required for continuous supply of power during day and night.

Solar cells produce direct current (DC) which must be converted to alternative current, (AC) using an inverter when used in existing distribution grids. This incurs some energy losses.

3.3.3 Concentrated Solar Power

CSP systems are used in generating heat and electricity on a large scale as in power plants and/or industrial processes. There are several types of CSP such as Parabolic Troughs, Fresnel Reflectors, Central Receiver (Heliostat), and Parabolic Dish. Parabolic trough technology is currently the most mature and commercially proven of the solar thermal electric technologies (Richter, Teske, & Rebecca, 2009; Sargent & Lundy, 2003).

.Parabolic trough-shaped mirror reflectors are used to concentrate sunlight on to thermally efficient receiver tubes placed in the trough's focal line. The troughs are usually designed to track the sun along one axis, predominantly north–south. Either water or thermal oil can be used as a thermal transfer fluid circulated in these receiver tubes. The fluid is heated to very high temperatures by the sun's concentrated rays reaching approximately 340°C in case of water and above 400°C in case of thermal oil. The produced steam is converted to electrical energy through a conventional steam turbine generator. CSP can be hybrid with other sources of energy so that electricity and heat can be still generated during cloudy periods or during the night.

Solar thermal power uses direct sunlight and should be installed in regions with high direct solar radiation. Among the most promising areas of the world are the South-Western United States, Central and South America, North and Southern Africa, the Mediterranean countries of Europe, the Middle East, Iran, and the desert plains of India, Pakistan, the former Soviet Union, China and Australia (ESTIA, Greenpeace, & SolarPaces, 2005).

New solar parabolic trough systems have been developed for small to medium applications where the sun direct radiation is converted into electricity and the waste heat is used in process applications such as cooling, heating and desalination. In the next chapters and for the purpose of this thesis solar parabolic trough will be termed as CSP.

3.3.3.1 Capacities & Cost

A CSP station would normally consist of the solar field and the power block. Based on a cost estimation offered by a German parabolic trough producer, the cost of the solar field is 310 €/m^2 of collectors (Solarlite, 2010). The cost of the power block depends on the type and size of the turbine. Based on the author's work experience in the field of CSP during the last 5 years and several feasibility studies carried out by the author through her employer Solarlite, the total cost of a small to medium scale CSP plant ranges from 3,000 to 5,000 €/kWe depending on the project's location and size.

A cost reduction of 15% in the solar field investment can be expected in developing countries, compared to USA/European price levels, due to lower labour costs (ESTIA, et al., 2005). Similar to WECS and PV, CSP have high potentials in the next years as the technology further develops and the installed capacities increase with the years worldwide.

3.3.3.2 Constrains & disadvantages

CSP might be difficult to install on the roof top of a building depending on its shape and surface area. It requires amble space on the ground in a nearby area to the project. Depending on the project location and size, the availability and cost of land might be a constraint. In the case of Sharm el Sheikh or newly developed areas on the Red Sea coast such as Marsa Alam, the price of land sold by the government is very low providing an incentive to investors and encouraging tourism development in that region. The resorts in that region would normally occupy the land with a seafront while the back areas are kept unused, enabling the installation of utility installations. In such cases, land requirement do not constitute a constraint for applying CSP.

3.3.4 Solar collectors

In this study, the author refers to non-concentrating solar collectors as solar collectors where the collector area (i.e. the area that intercepts the solar radiation) is the same as the absorber area (i.e., the area absorbing the radiation). The following types of solar collectors are further considered in the design development of solar resort within the scope of this thesis:

- Domestic water heating: a solar collector based on the principle of thermosiphonic circulation was recommended by a local supplier in Egypt for the project at Sharm El-Sheikh. The price of Euro 1000 for 160 litre tank capacity and 2 m^2 of collector area was offered.
- Swimming pool heating: A general rule of thumb is that the collector surface area should equal at least one half of the pool's surface area. In a relatively sunny climate, this additional heating helps extend the swimming season into spring and autumn (NREL, 2000). The author could not get any cost information from local suppliers; however, internet research indicates that the initial investment for a solar pool heating system is $3,000 to $5,000 (equiv. €2,140 to €3,570) for a typical 27 to 37 square meter of pool surface area. Based on which a cost of 125 $/m^2 (equiv. 90 €/m^2) is further considered for the purpose of this study.

3.3.5 Solar Cooling

Solar cooling technologies use solar thermal provided through solar collectors to power thermally driven cooling machines. Air conditioning among other cooling applications have a high coincidence with the availability of solar irradiation. The combination of solar thermal and cooling obviously has a high potential to replace conventionally cooling machines based on electricity (El Asmar, 2008). A handbook for planners was prepared by the International Energy Agency, IEA, where the different systems are explained in details along with price indications (IEA, 2007). There are many ways to convert solar energy into cooling or air-conditioning processes, yet, it is not within the scope of this thesis to explain and compare all systems. The author has chosen absorption chiller system to adopt in the design of solar resort since it is most common thermally operated systems and well known in Egypt.

In addition to the IEA handbook, the author used market information gathered for feasibility studies undertaken for her latest employer Solarlite (2010) with regards to solar cooling. In view of that, the cost considered later for the solar cooling system is based on 650 €/kW of cooling capacity excluding the energy source but covers the chiller, pumps, cooling tower and other components required.

3.3.6 Solar desalination

In the past few decades, a lot of desalination methods were invented. In the latter half of the twentieth century, multi-stage flash (MSF), multi-effect distillation (MED) and reverse osmosis (RO) and other methods have succeeded greatly (Macoun, 2000). In MSF & MED systems, the solar water is heated by an indirect method where the solar collector system is a separate system apart from the desalination system. The heat produced in the solar collector system is sent to the distillation system by fresh water (He, Juyuan, & Mingxian, 2010). Systems that use thermal methods with a daily capacity around 100 m^3, the cost varies between 2.00 and 8.00 €/m^3 (Karagiannis & Soldatos, 2008).

In RO stations, renewable power produced through PV, CSP or WECS can be used as an RE source. The specific energy consumption of RO plants in the region is typically 6.5–9 kWh/m^3, depending on the salinity of the intake water seawater and the age, efficiency and configuration of the plant (Lamei, van der Zaag, & von Münch, 2008). RO plants for seawater desalination has a unit cost ranging from 1.26 to 2.84 €/m^3 (Karagiannis & Soldatos, 2008).

An internal study carried out by Solarlite in 2009 regarding the potential of using parabolic troughs for solar desalination indicated that for medium to large scale capacities, greater than 100 m^3/day, requires not only large amount of thermal energy but also a large land area for system installation. Moreover, the costs are not competitive with RO systems. Therefore, the author will not be considering solar thermal driven desalination plants and would focus on RO system operated by renewable generated power.

4 Hotel Industry and design practices in Sharm el Sheikh

This chapter provides background information about the current situation of the hotel industry in Sharm el Sheikh. The first part starts with information about the location and climate conditions of Sharm el Sheikh as an introduction to understanding the current local practices. The second part of this chapter presents the results obtained from a walk through audit conducted among resorts in Sharm el Sheikh (Figure 4-1). The results are presented per guest-night representing a preliminary benchmark for hotels along the Red Sea coast in Egypt that is later used by the author in developing the solar design alternatives.

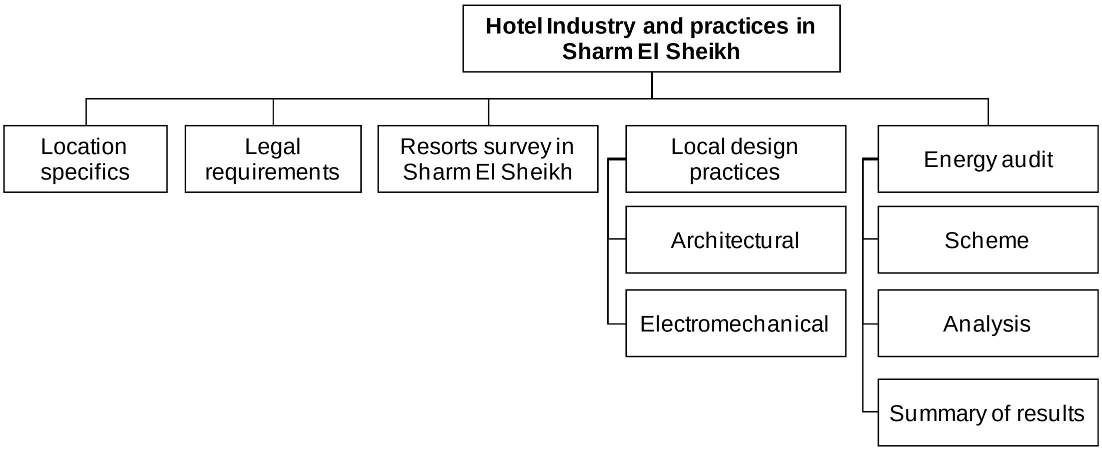

Figure 4-1: Outline of chapter 4

4.1 Location specifics

Lying at the southern flank of the Peninsula where the two gulfs of Aqaba and Suez meet with the Red Sea, Sharm El-Sheikh is the biggest and most important city of Sinai considered as the most famous seaside resort in Sinai. The city is subdivided into five homogeneous centres namely: Nabq, Ras Nusrani, Naama Bay, Umm Sid and Sharm El Maya. However, the increasing development of Sharm el Sheikh is such that they will soon form one settlement (Figure 4-2).

Located at latitude 27° 58' 37" N and longitude 34° 23' 40" E, Sharm el Sheikh enjoys a very arid desert climate with two main seasons, both of which are dry seasons. Figure 4-3 shows the average air and water temperatures in Sharm el Sheikh throughout the year. The winter months are from November to March, during which the day temperature is still warm but the night time temperature can drop to about 12°C and lower inland in the desert. The annual rain fall is zero; during the winter months it can rain for a few seconds and every few years a storm can come through where it absolutely chucks it down with floods and power cuts. The summer weather is very hot and dry with low humidity making the high temperatures a lot more bearable. The temperature during the day can be in the forties and decrease during the night time to mid thirties.

Figure 4-2: Location of Sharm el Sheikh (Wikipedia)

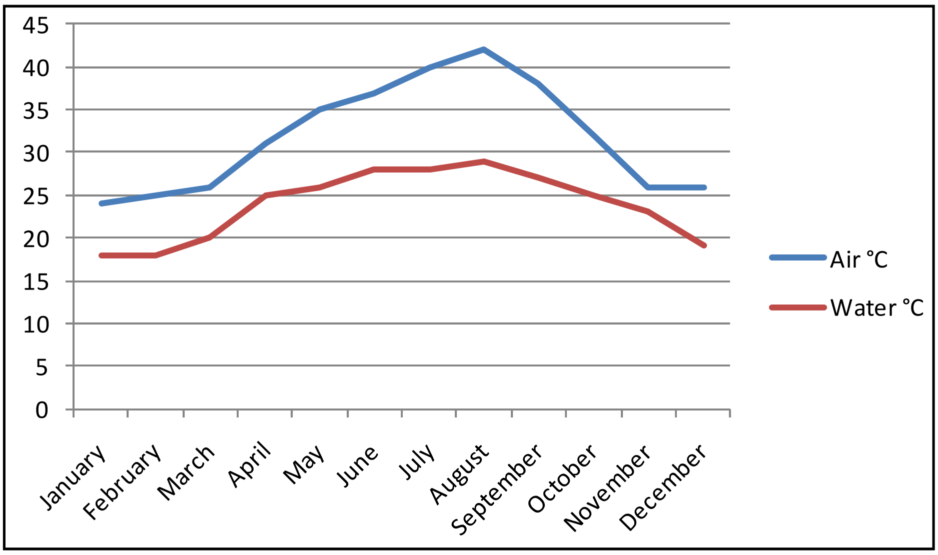

Figure 4-3: Average air and water temperatures in Sharm el Sheikh (ESIS)

4.2 Legal requirements for five stars resorts

The MoT has defined a set of standards for different classes of resorts. These standards are to be respected by architects during the development of a new resort project. The following is a summary of the standards set for four & five stars resorts:

- Location: special location according to the nature of the region.
- Building the design of the resort should be based on separate buildings formation. The percentage of buildings to landscape is defined as 20%.
- Guest room area: 35 m^2 including bathroom in addition to a terrace of 2x4 m^2 at least.

- Reception and lobby area: 3 m^2 per room for the first 100 rooms and 1 m^2 for every additional room.
- Restaurants: 3.5 m^2 for each guest room should be made available.
- Outlets: at least a bar and a night club should be available.
- Conference room: at least 250 m^2.
- Guest room electrical equipment: each room should contain at least 6 lamp units, hair-dryer, mini-bar and a TV 21 inch
- Elevators: Guest and good lifts are required for any building consisting of more than 1 storey above ground level.
- Public areas air-conditioning: an HVAC system must be provided for reception and lobby areas.
- Guest rooms air-conditioning: an HVAC system must be provided for all guest rooms with a temperature from 18 to 25 Celsius.
- Swimming Pools: for at least 60% of the accommodating capacity based on a swimming area of 2.25 m^2 per guest in addition to a children's swimming pool and showers.
- Beauty centre, souvenir shops, and a bank should be made available in the resort.
- The resort should include a staff restaurant and a clinic for both guests and staff.
- Health club, Kids club and open courts should be provided for.
- A laundry with washing and dry cleaning facilities is required.
- Kitchen: at least a main kitchen covering the service of total capacity and a satellite kitchen according to the outlets requirements
- Cold rooms for garbage storage until disposal through an environmentally approved method.
- A waste water treatment must be provided on site.
- Emergency generator: must be provided covering 25% of the peak power and sufficient to operate public area, kitchens, cold rooms, and a lamp per guest room.

4.3 Survey of resorts in Sharm el Sheikh

Tourism industry in Sharm El-Sheikh is considered the core of its development. Many luxury hotels have flourished along the Red Sea Coast in Sharm el Sheikh. They all offer a variety of facilities including plenty of entertainment, sports and leisure activities, demanded by an international clientele visiting the city during summer and winter.

The author carried out a survey among the luxury resorts in Sharm el Sheikh with the main objective of assessing the energy consumption and its utilisation in five stars resorts. The survey also aimed at understanding the factors impacting the choice of decision making in design development. In addition to gathering data directly from the resorts, tourism and government authorities were also approached for supporting information.

According to the latest data provided by the Information Centre of Sharm el Sheikh Governorate, there are a total number of 126 resorts and hotels in Sharm el Sheikh; of which 29% are five stars hotels, 30% are 4 stars and the remaining are of lower classes (Figure 4-4). That is to say, more than 60 resorts in Sharm El-Sheikh provide high standard services and facilities which consequently results in higher energy demand. It was also stated that in 2007 the total number of rooms in Sharm el Sheikh reached 14,760. Figure 4-5 indicates the numbers of resorts versus their accommodation capacities. It is noticed that the majority of resorts have a capacity of 200 to 500 guest rooms which according to resort developers resembles the most economic scenario considering the existing room rates in Sharm El-Sheikh.

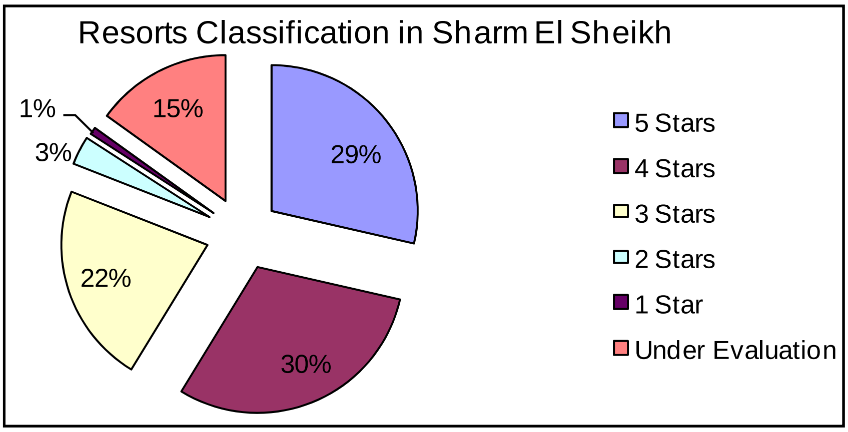

Figure 4-4: Resorts classification in Sharm el Sheikh

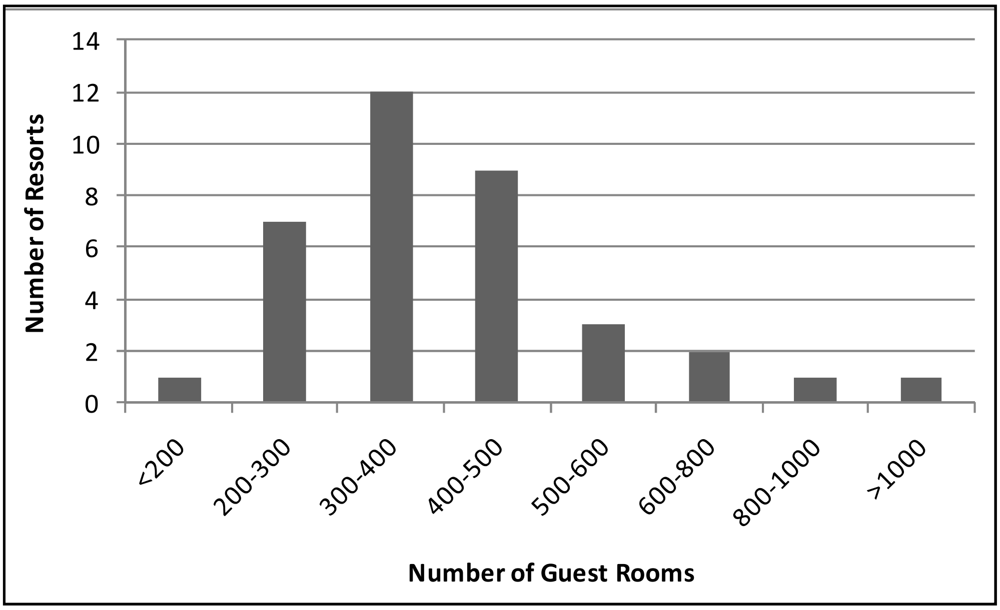

Figure 4-5: Resorts accommodation capacities in Sharm el Sheikh.

4.4 Local design practices for resorts

Based on the author's work experience in the field of resorts development from the year 2000 to 2005 and the information gathered during the survey, this section explains the current practices and parameters take into account during the design phases of resorts in Sharm el Sheikh. The project stakeholders may have a direct or indirect impact on the design and implementation of the resort and the relative decisions made. The impact strength will vary in each case depending on the influential power of the stakeholder and the existing legislations. Figure 4-6 illustrates the different stakeholders involved in the development of a resort project. The key stakeholders influencing the project during the early design stages of the project are follows:

- The investor and owner who usually own the land and would continue to own the project are responsible of making the funds available for the project implementation. During the design and construction phases of the project, the owner is mostly concerned about the capital investment cost affecting his decisions in technology choices.
- The hotel management could be either a hotel chain with experience in hotel operation or a local hotel operator with limited experience. In few cases, the hotel management would also partly invest in the project. Usually the hotel management prefers to have the state-of-art in its project regardless of the investment cost. They are more concerned about operation and maintenance costs which are reflected in the profits they yield to the owner.
- The architect and design team set the technical specifications of the building design and required equipment influencing the choice of technologies and subsequently the energy performance of the project. In most cases, they are bound by the owner's tight budget and have limited flexibility.
- The local authorities such as the building, environmental and tourism authorities have at this stage no great role on determining or controlling the resort's energy efficiency at this stage. Their roles are restricted within the previously mentioned resort standards.

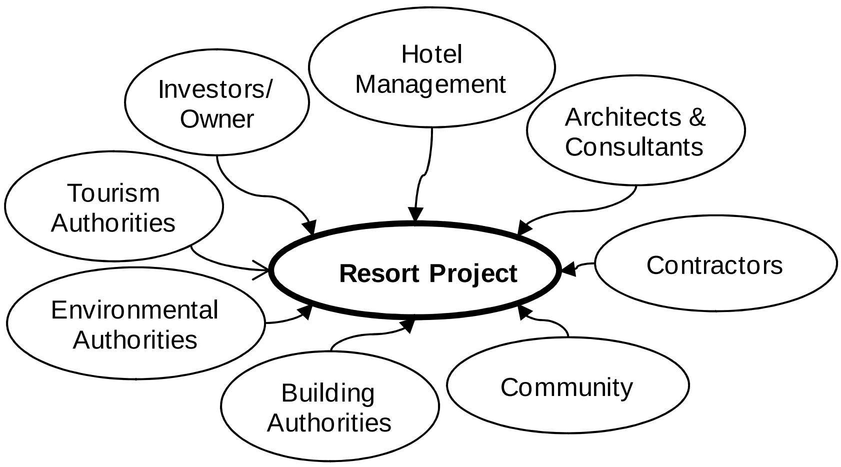

Figure 4-6: Stakeholders in a resort project

4.4.1 Architectural design practices

Most of the resorts are designed to have maximum view of the sea and/ or the swimming pools in order to add this advantage to the rooms attributes. The result is high exposure of the facades to sun radiations with little attention paid to the type of glazing, shading and insulation. The resort layout differs according to the shape and area of the land as well as the minimum number of guest rooms stated by the owner. It is common that the resort will consist of a combination of the following building types:

- Multi storey building with maximum four stories high;
- Cluster of blocks where each block consists of a ground and first floor and would contain up to 6 guest rooms;
- Individual chalets or bungalows.

The architect is usually under pressure from the owner to maximise the number of guest rooms in order to increase the return of investment. Hence, most resorts are designed consisting of multi-storey buildings and/or cluster of blocks rather than chalets or bungalows.

The types of materials chosen for the construction of resorts are the same used in other commercial and residential building:

- Structure skeleton: it is a common practice that the skeleton (columns and beams) of the buildings are constructed out of reinforced concrete due to its local availability and being the most economic solution compared to wood and steel.
- Exterior walls: Cement blocks, hollow mud bricks or red bricks are used. It is very seldom that thermal insulation is used.
- Interior walls: red bricks are mostly used followed by cemented blocks.
- Slabs: are constructed out of reinforced concrete and covered with ceramic and marble tiles.
- Roofs: reinforced concrete is used with tar insulation. In case of dome roofs, bricks are used.
- Windows: Single tinted reflecting glass is the most common type used. Double glazing is rarely used.

4.4.2 Electromechanical design practices

In any hotel various types of energy are required to operate its engineering services installations, thus maintaining a suitable indoor built environment (thermal, visual and indoor air quality, etc.) and providing guests and staff with quality services. These services mainly include heating, ventilation & air-conditioning, lighting, vertical transportation and hot water supply. Additional heat and power are also consumed in the resort's kitchen and laundry facilities. In Sharm el Sheikh, three types of energy, electricity, gas and diesel fuel, are normally used to operate the following electromechanical installations:

- HVAC: The main function of HVAC is to provide cooling rather than heating. Cooling is usually required throughout the whole year. The typical design conditions for a resort are: 23°C temperature; 50% relative humidity; 0.15-0.25 m/s air movement; and 7-9.5 l/s ventilation. The HVAC system could be either a central or distributed system. The most common central systems used in Sharm el Sheikh resorts are of electrically operated central air/water cooled chilled type while the distributed systems consist of split units. Until date Egypt does not have energy efficiency standards enforcing the minimum efficiency requirements for air conditioning and heating equipment for either residential or commercial buildings.
- Steam and hot water systems: fuel operated steam and hot water boilers are the most common used for the generation of DHW and heating required for laundry, kitchen equipment and swimming pools heating. DHW can be also provided through other means such as electric water heaters or solar water heaters.
- Energy management systems (EMS) are necessary in achieving energy efficiency by optimising and eliminating the manual control of lighting and equipment operation saving energy. Very few hotels mentioned using a simplified form of EMS. It is not yet common practice to have a complete EMS.

- Water supply: Fresh water is supplied through privately owned seawater desalination plants as there is no municipal water distribution system in Sharm el Sheikh. Most of the four & five stars resorts have their own desalination plant within their resort premises. Nearly all desalination stations constructed on the Red Sea resorts are of RO type.
- Waste water treatment: similarly, there is no municipal sewage network in Sharm el Sheikh and, hence, resorts are required to treat their wastewater and to reuse or dispose of the treated effluent in an environmentally friendly way. The most common waste water treatment system used is the activated sludge type which meets the strict quality required for irrigation if properly operated.
- Power supply systems: Sharm el Sheikh is one of the few towns on the Red Sea coast which have access to the public electricity grid. While most of the resorts are connected to the grid, a few resorts depend on diesel generators for their power supply.

4.5 Energy audit scheme

4.5.1 Audit procedure

The main aim of the energy audit scheme is to identify if there is a common trend in energy and water consumptions in Sharm el Sheikh resorts. The first step in the audit was to define resorts with common features to be audited in order to be able to compare the results. For example, a five stars resort will provide the same level of services and amenities and would have similar average room area, devices and equipment; an experienced hotel management will have more or less similar energy management awareness that might be different from local management companies with less experience. Accordingly, the audited resorts were selected to meet the following criteria:

- Resorts classified as five stars by the MoT;
- operated by experienced and international hotel management;
- with a minimum number of 200 guest rooms;
- providing fresh water through on site desalination station;
- with a waste water treatment system; is treated; and
- reusing treated waste water in landscape irrigation.

The second step in the audit scheme was to formulate the audit questionnaire which is based on the literature review carried out on energy use in hotels. The questionnaire aimed at collecting data covering the following issues:

1. General information:
    - Hotel name & location
    - Classification
    - Number of guest rooms
    - Total surface area
    - Date of opening
    - Date of latest renovation
2. Number and type of facilities such as restaurants, outlets, swimming pool etc...
3. Distribution of buildings
4. Size and type of HVAC
5. Guest room electrical consumption

6. Energy production system
7. Water production system
8. Waste water treatment system
9. Environmental practices
10. Energy consumption (monthly or daily data)
    - Overall consumption
    - Department/distributed consumption
11. Water consumption (monthly or daily data)
12. Guest numbers and occupancy
13. Contact person

The questionnaire was first sent to a list of five stars resorts which met no response at all. This was followed by onsite interviews with 14 resorts in 2007 & 2008 where the author met with the people in charge at the different resorts. Due to time and financial constraints in addition to general reluctance and low levels of response and support from the resorts, the author was not able to interview all five stars resorts in Sharm el Sheikh. Out of the 36 resorts classified as five stars, 14 resorts, fulfilling the above set criteria, were interviewed forming a response rate of 39%. Only 7 out of those 14 resorts provided consistent and complete information that could be further analysed and used, representing 19% of the five stars resorts in Sharm el Sheikh. Nonetheless, it is worth mentioning that not all the 36 five stars resorts are operated by international management companies. Also, several of those resorts have been recently constructed and do not have records of operational data. Respecting their data protection policy, it was agreed to present the results of the survey anonymously without mentioning of the resorts.

Table 4-1 gives an overview of the seven audited resorts that provided adequate and consistent information. The gross area here is the total surface area of the resort divided by the total number of guest rooms. It can be noted that except for resorts 5 & 6, the resorts have a close range of gross area per guest room. This is attributed to the large landscape areas in Resorts 5 & 6 compared to the other 5 resorts. Resort 1 is the only resorts that have been in operation for more than 10 years. The other resorts have an operation period from 3 to 7 years. All of the seven resorts are classified as five stars and have a capacity lying between 200 to 550 guest rooms (GR) except for Resort 5 having a capacity of 835 GR.

Resort reference	Classification	Guest room number (GR)	Opening date	Total surface area m^2	Gross area m^2/GR
Resort 1	5 stars	520	1996	120,000	231
Resort 2	5 stars	314	1999	68,000	217
Resort 3	5 stars	401	2000	70,000	175
Resort 4	5 stars	210	1998	60,000	286
Resort 5	5 stars	835	1999	357,000,00	428
Resort 6	5 stars	344	2004	150,000	417
Resort 7	5 stars	552	2001	80,000	161

Table 4-1: Overview of the seven interviewed hotels

4.5.2 Audit results

The operational data gathered from the resorts were available in diverse levels of details and formats according to the differing management systems. In order to form a common basis for comparison, the author sorted out the relevant and transferred them into a number of excel sheets creating a template to calculate the consumption of each resort. The tables comprised the following main data:

- Monthly consumptions for electricity, fuel, LPG and water.
- Annual total number of guests
- Annual total number of occupied guest rooms.
- Unit price of related consumables such as power, fuel and LPG

The compiled data was then used to calculate the occupancy and consumptions per guest-night. Figure 4-7 shows the availability of data versus the opening date of the resort. It is noticed that only two resorts out of seven recorded their consumption from first year of operation while the remaining five resorts started recording their consumptions only after two years or even more from the day of opening.

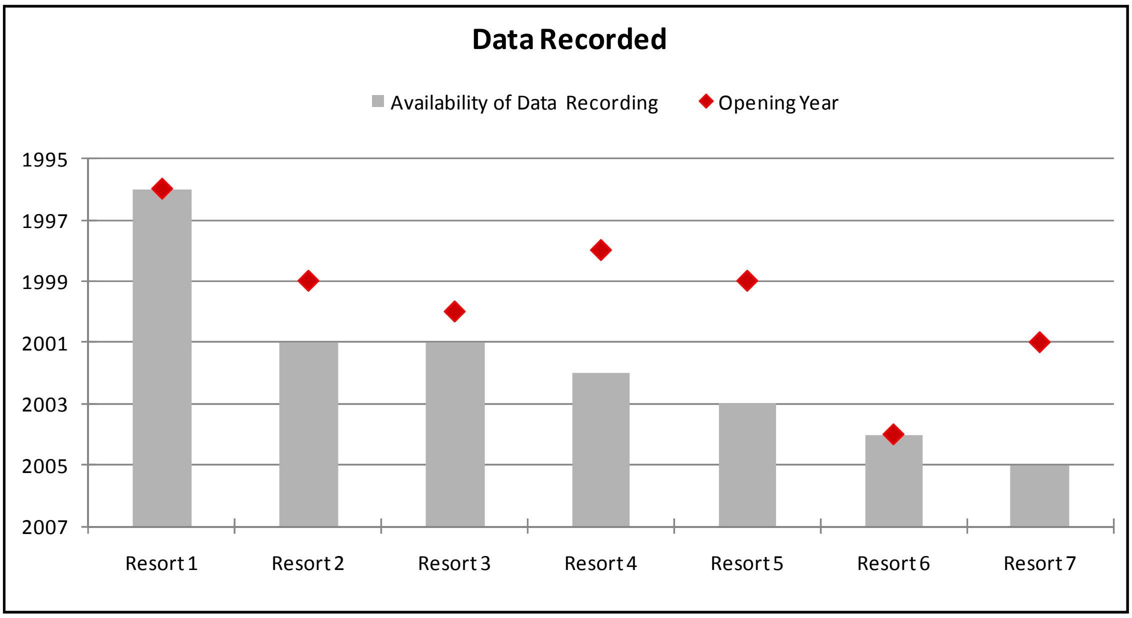

Figure 4-7: Data recorded versus year of opening for the audited resorts

4.5.2.1 Resorts characteristics

The characteristics and features of the seven resorts are compared and summarised in Figure 4-8; the following was observed:

- Swimming pools: all resorts have more than 1 swimming pool with at least 1 heated during the winter time.
- HVAC: the public areas of all resorts are cooled using central air conditioning with chillers systems. Two out of seven resorts use central chiller system for the cooling of the

guest rooms while one resort uses split units for cooling their guest rooms. The remaining 4 resorts use a mix of central and split systems to air condition their guest rooms.

		Resort 1	Resort 2	Resort 3	Resort 4	Resort 5	Resort 6	Resort 7
Facilities & Amenities	Restaurants	3	3	4	3	5	3	5
	Indoors Bars	3	1	3	1	4	3	1
	Outdoors Bars	3	3	4	4	11	2	1
	Health Club	✓	×	✓	✓	✓	✓	✓
	Swimming Pools	2	6	4	2	10	2	4
	Heated Swimming Pools	1	1	2	4	1	1	1
	Main Kitchen	✓	✓	✓	✓	✓	✓	✓
	Satellite Kitchens	-	2	2	2	4	2	3
	Laundry	✓	✓	✓	✓	✓	✓	✓
HVAC	Public Areas A/C	Chillers	Chillers	Chillers	Chillers, Dx & Spl	Chillers	Chillers	Chillers
	Central A/C Rooms %	25,38%	100%	100%	-	35,93%	36,1%	59,78%
	Split Unit A/C Rooms %	74,62%	-	-	100%	64,07%	63,9%	40,22%
Energy Resources	Lighting	Grid Electricity	Grid Electricity	Grid Electricity	Grid Electricity	Grid Electrcity	Grid Electricity	Grid Electricity
	HVAC & equipment	Grid Electricity	Grid Electricity	Grid Electricity	Grid Electricity	Grid Electrcity	Grid Electricity	Grid Electricity
	Domestic hot water	Fuel	Fuel	Fuel	Solar thermal	Fuel	Fuel	Fuel
	Kitchen equipment	Grid Electricity	Grid Electricity	75% LPG & 25% Grid Electricity	Grid Electricity	LPG & Grid Electricity	LPG & Grid Electricity	95% LPG & 5% Grid Electricity
	Laundry steam	Fuel	Fuel	Fuel	Solar thermal	Fuel	Fuel	
	Guest Room Peak kW		~2.0	~4.0	~6.0	0.85~0.90	4.0~6.0	4.2~6.0
Water	Domestic water	DS	DS	DS	DS	DS	DS	DS
	Irrigation water	STP	STP	STP	STP	STP	STP	STP
Environmental Practices	Management Systems							
	Energy management Sys	×	×	×	×	×	×	×
	Energy saving lamps	×	✓	✓	✓	×	×	×
	Power savers	×	✓	✓	✓	✓	✓	✓
	Faucet water savers	×	×	×	✓	✓	✓	✓
	Flush toilet savers	×	×	×	✓	×	✓	×
	Double glazed windows	×	×	✓	×	×	×	×
	Wall insulation	×	×	×	×	×	×	×

DS = Desalination Station STP = Sewage treatment Plant

Figure 4-8: Overview of the seven audited resorts

- Electricity: in all seven resorts, electricity is provided through the grid and is used for lighting and HVAC purposes.
- DHW: Only one resort used solar thermal energy for supplying DHW while the other six resorts used boilers operated by diesel fuel.
- Kitchen: All resorts have a main kitchen and at least two satellite kitchens except for Resort 1 which has no satellite kitchen. Four resorts use a mix of LPG and grid electricity to operate the kitchen equipment while the other 3 resorts depend 100% on grid electricity.
- Laundry: All resorts are equipped with a laundry facility. All resorts use diesel fuel for supplying steam or hot water required by the laundry equipment except for Resort 4 which stated using solar thermal energy.
- Guest rooms: The peak power demand per guest room varies between 2 to 6 kW. The first resort did not provide this information while Resort 6 claimed a very low value of 0.95 kW. The author has no clarification for this exceptional low value.
- Water: Each of the 7 resorts have their own desalination plant and waste water treatment plant where the treated water is used for irrigation purposes.
- Power savings measures: Resort 1 does not apply any energy savings measures which might be contributed to the fact that the resort was built before 1996 and didn't undergo any renovations. Five resorts used power savers in the guest rooms while 3 resorts only used energy saving lamps.
- Water saving measures: Only 3 resorts took measures towards installing faucet water savers in an attempt to reduce water consumption.
- Building energy efficiency measures: None of the resorts used thermal insulation in their external walls while only 1 resort used double glazing in their window façades.

4.5.2.2 Resorts occupancy

The occupancy of any resort is determined by the guest to room ratio (GtR) and the room occupancy. The GtR shows the average number of guests occupying one sold room. It is defined as the ratio of guest-nights or bed-nights to the room-nights occupied. Meanwhile, the room occupancy is defined as the number of room-nights occupied divided by the number of room-nights available, multiplied by 100%. Both factors GtR ratio and room occupancy have a direct impact on consumption rates as illustrated in the next section.

Figure 4-9 depicts the GtR ratio of the audited resorts between the years 1995 and 2006 where it varies between 1.80 and 2.0 yielding an average value of 1.89. In Figure 4-10, the average yearly room occupancy lies between 70% and 90%. In the period from 2002 to 2006, five out of the seven resorts showed same trend in occupancy, where all of the resorts shared a peak occupancy in the year 2004. The occupancy figures of the remaining two resorts are available only from 2004 and 2005 but have still followed the same occupancy pattern of the other resorts.

During the interviews all resorts declared that hotel operation in Sharm el Sheikh is considered to be non-seasonal and is in function all year round with carrying occupancy rate from one month to the other. Only four resorts out of the seven resorts could provide detailed monthly data regarding the number of rooms occupied (see Figure 4-11). It is observed that Resorts 3 & 4 follow almost the same occupancy pattern with peak occupancy occurring from February to May and from September to December. Although the summer months are too hot for foreigners causing less occupancy, yet the resorts are still occupied by an average rate of ca. 53%. Resort 6 shows a different behaviour where occupancy during the summer months exceeds 80%. This is explained by the type of clientele and resort's marketing policy. It was indicated that some resorts focus on foreign visitors causing the high occupancy during the cooler months from September to May while other resorts depend also on local visitors who usually make their holidays during the summer months from July to September.

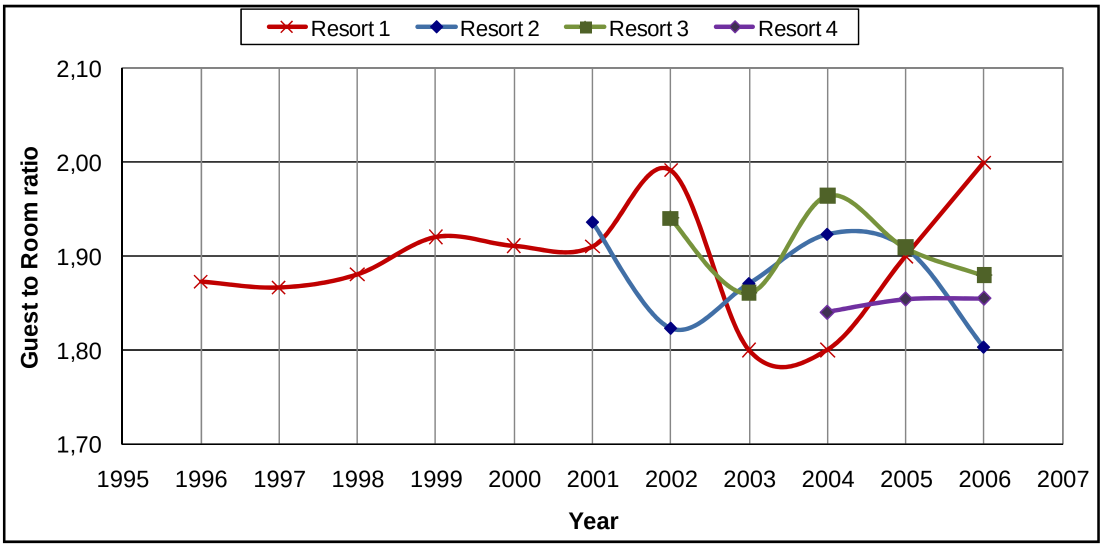

Figure 4-9: Average Guest to Room ratio at Sharm el Sheikh resorts

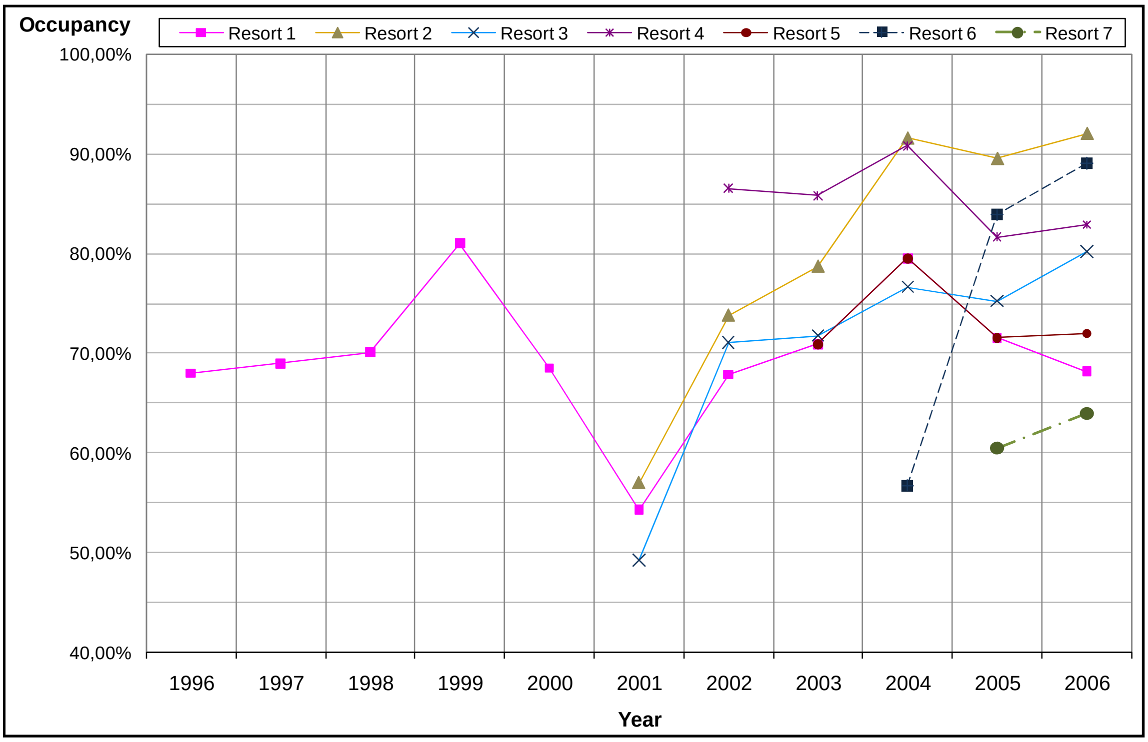

Figure 4-10: Room occupancy rate at Sharm el Sheikh resorts

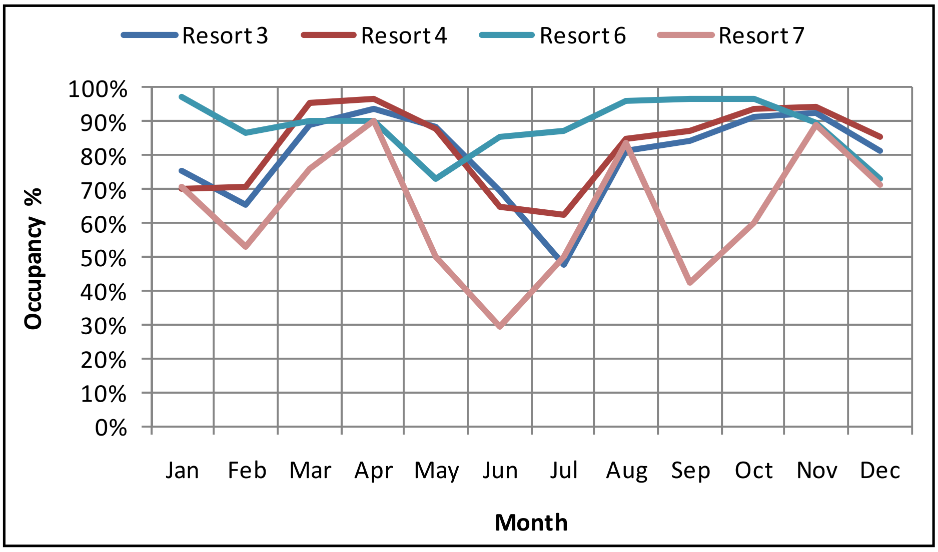

Figure 4-11: Monthly room occupancy rate at Sharm el Sheikh resorts in 2006

4.5.2.3 Resorts energy consumption

As outlined earlier in chapter 3, the energy performance of the resorts would be expressed in this study kWh, litre and kg per guest-night (GN) for electricity, fuel and LPG respectively. The equivalent total cost of consumed energy per guest-night is calculated for each of the seven audited resorts in order to compare their overall energy performances.

4.5.2.3.1 Electrical consumption

Electricity is normally used to power most of the resorts services such as lighting, TV, elevators, part of the cooking devices, electrical appliances, laundry equipment, HVAC system, desalination plant and waste water treatment plant.

The electricity consumption of each resort was calculated using their monthly electricity billing information. There was no information available on the consumption distribution showing the consumption of each department or function which could be used by the management in identifying the high consumers. A few resorts mentioned the intention of installing several electricity meters within the premises of the resort to monitor the energy performance of different departments and buildings. There were also neither daily consumption profiles nor hourly data available which could show the peak periods during the day. This kind of detailed information is important for energy management systems where the energy loads can be monitored, controlled and optimised by redistributing the operation hours of some equipment.

The analysed data for the electricity consumption of each resort is presented in Figure 4-12, where it can be observed that the average electricity consumption lies between 38 & 58 kWh per guest-night. This range is applicable for the seven resorts under study and over the different years with the exception of two resorts: Resort 3 in 2001 & 2002 and Resort 2 in 2001 where they show very high consumption. No clarification was provided by the resorts technical staff for these excessive values. On comparing those figures of Sharm el Sheikh to those mentioned in Table 3-3, which show the consumption rates in different parts of the world, it is noted that electricity consumption in Sharm el Sheikh is comparable to Europe and New Zealand while higher than that of Cyprus and Majorca. The benchmark values mentioned at the beginning of chapter 3 could not be used in this case for judging since they are expressed in kWh/m^2 which is not calculated in our case due to lack of information regarding the floor areas.

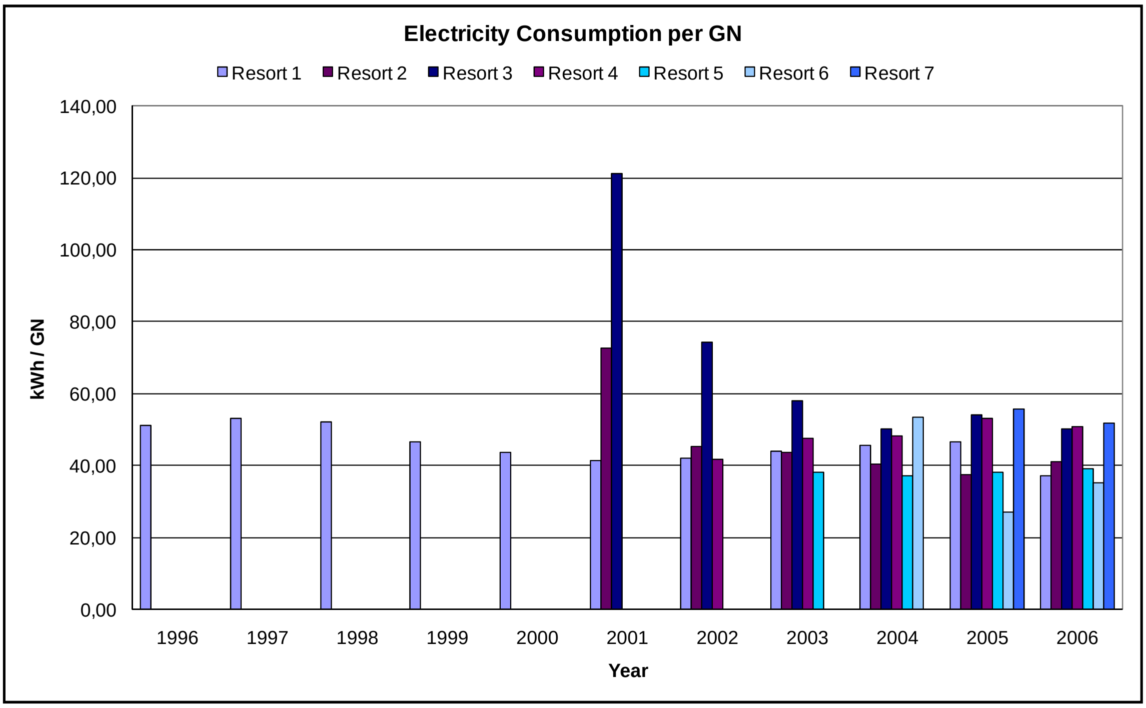

Figure 4-12: Average electricity consumption per guest-night at Sharm el Sheikh resorts

The monthly consumption graph in Figure 4-13 shows the consumption profile in the year 2006. It is observed that during the summer time from June to October there is an increase in the power consumption. The other years showed same consumption behaviour which is justified by the high summer temperatures and cooling needs.

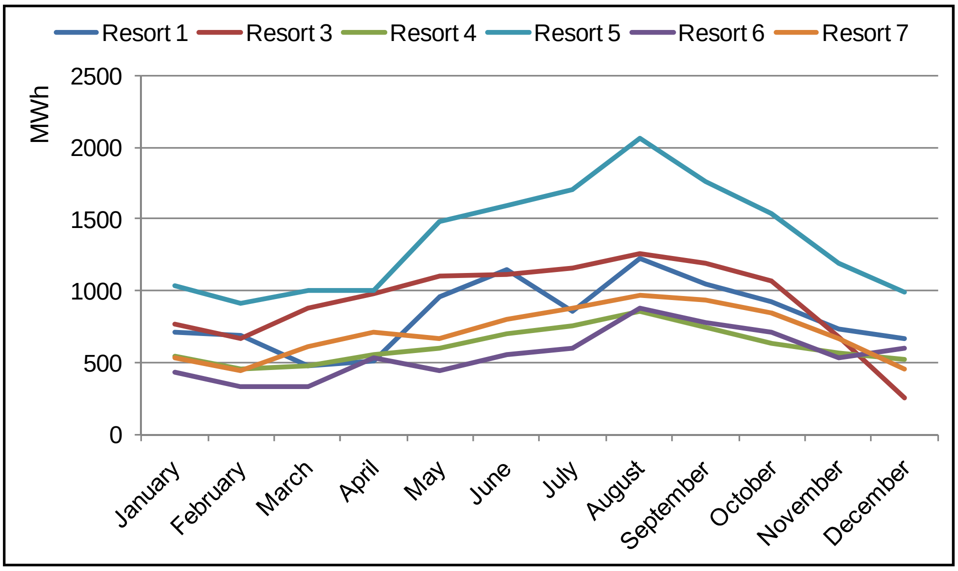

Figure 4-13: Monthly electricity consumption in 2006 at Sharm el Sheikh resorts

4.5.2.3.2 Fuel consumption

Diesel fuel is used in resorts mainly for steam/hot water boilers and power generators. All resorts have an emergency generator for cases of electricity cut-off and as stipulated by the MoT. It was stated by all the audited resorts that the fuel consumption of the generators is negligible as they are only operated for very few hours per year and they do not experience long periods of power cut-off from the grid.

Out of the seven audited resorts six resorts use steam or hot water boilers for supplying steam and domestic hot water. All of the boilers operate using diesel fuel. Resort 4 is the only that do not use boilers and depend on solar thermal collectors for the provision of hot water for domestic and laundry usages and, hence, has almost no fuel consumption at all. The monthly fuel billing information was used to calculate the fuel consumption per guest-night. Again, there were neither daily consumption profiles nor hourly data available which could be used in determining the peak periods during the day.

Figure 4-14 presents the commuted valued of the fuel consumption for each resort. The average fuel consumption lies between 1.5 & 3 litres of diesel per guest-night. Resort 3 showed once more higher consumption rates in 2001 & 2003 with no explanation declared by the technical staff.

The total monthly fuel consumption for the year 2006 is presented in Figure 4-15. It is noticed that the consumption rate drops during the spring and summer periods from May to October which is attributed to the additional water heating required for DHW and swimming pools during winter time and lower heating demands during the summer time.

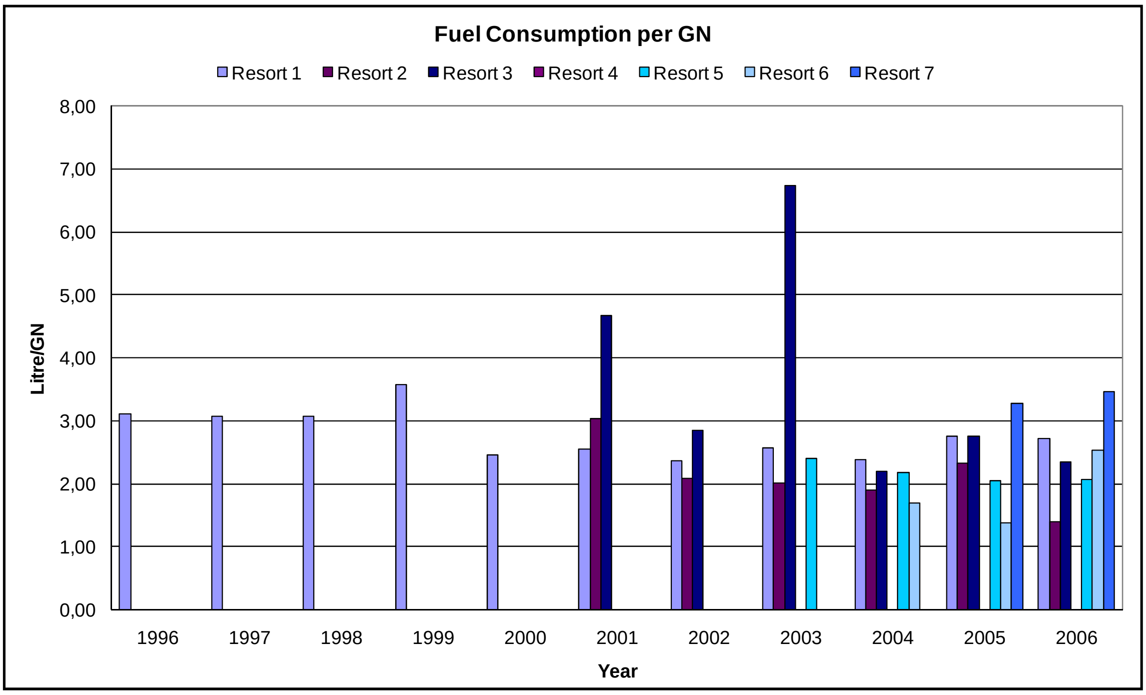

Figure 4-14: Average fuel consumption per guest-night in Sharm el Sheikh

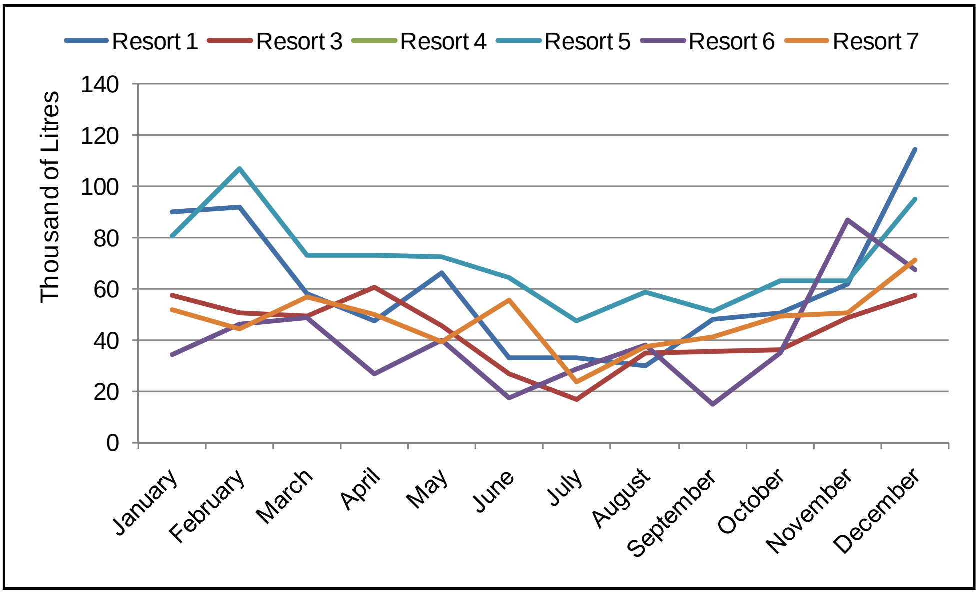

Figure 4-15: Monthly fuel consumption in 2006 at Sharm el Sheikh resorts

4.5.2.4 LPG consumption

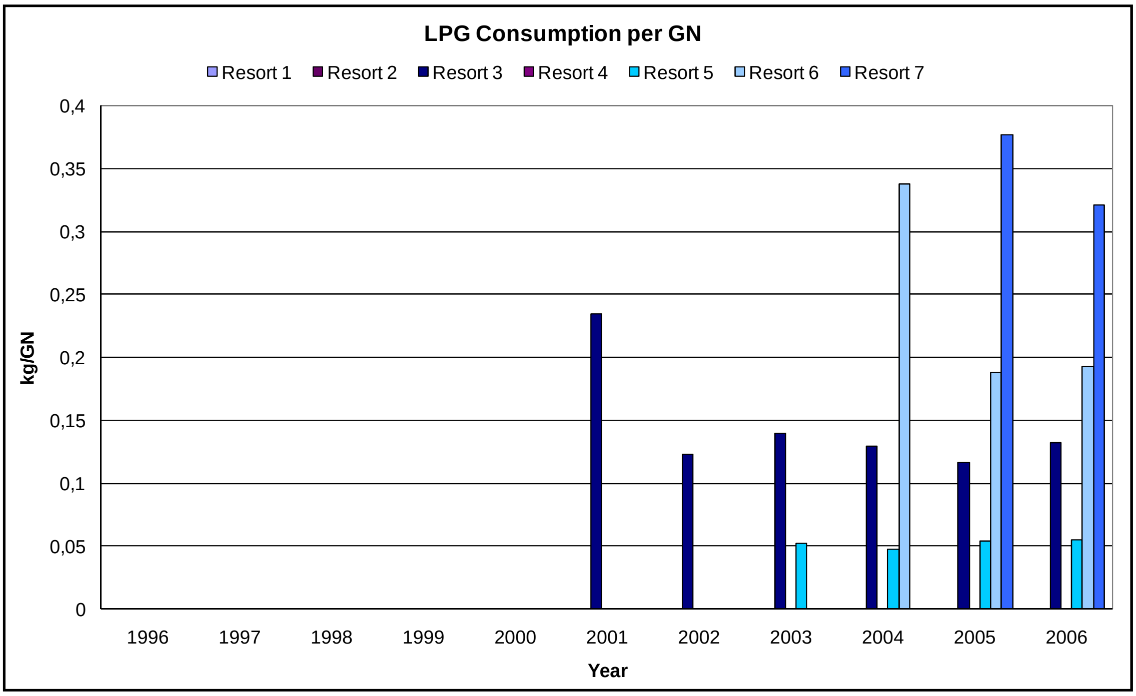

Figure 4-16: Average LPG consumption per guest-night at Sharm el Sheikh resorts

LPG is used usually to operate cooking equipment especially ovens. Only 4 out of the seven resorts use a mix of gas and electricity kitchen equipment. The gas consumption differs from one resort to the other depending on the proportion of gas to electric equipment. Some resorts depend on 95% gas supply, others on 75% or 50%. This variation is clearly seen in Figure 4-16, where there is a substantial difference in consumption rates from one resort to the other. For example, although the consumption rates of Resorts 3 & 5 differ from ca. 0.15 to 0.05 kg/GN respectively, yet each resort maintain a steady consumption rate over the years. The author could not find any explanation for the fact that although Resort 7 uses LPG for 5% only of its kitchen equipment, yet its LPG consumption is very high compared to Resort 3 where LPG constitutes 25% of the energy used by its kitchen equipment.

Figure 4-17 depicts the monthly LPG consumption in the 4 resorts during the year 2006. Resorts 3 & 5 show a nearly regular consumption through the year while Resorts 6 & 7 show several peak periods with no clear explanation. In the other years, the consumption of those two resorts still show irregular consumption behaviour.

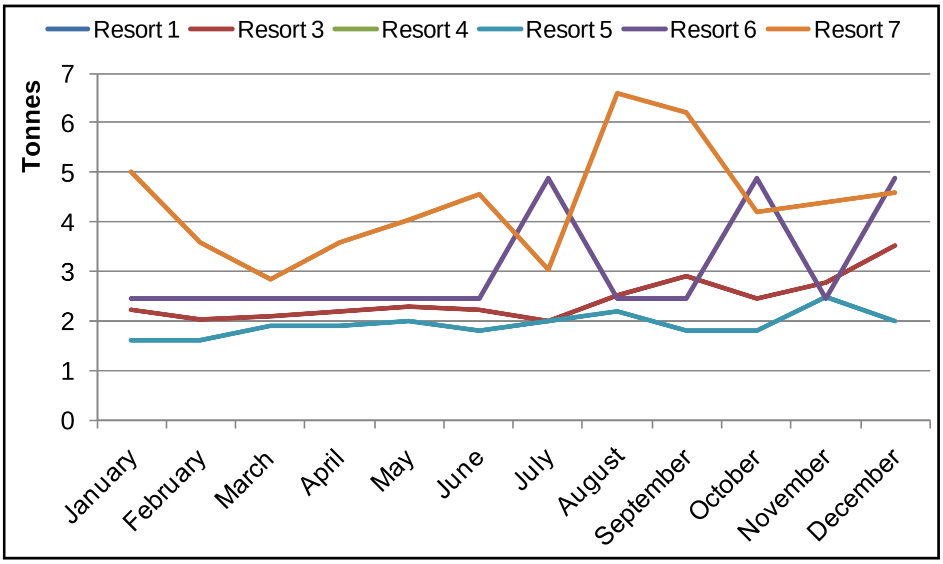

Figure 4-17: Total monthly LPG consumption in 2006 at Sharm el Sheikh resorts

4.5.2.5 Water consumption

Water is consumed not only for domestic uses but also in the swimming pools. Water consumption at any four or five stars resort in Sharm el Sheikh plays an important role in the total overall energy consumption and has a direct impact on power consumption through the following factors:

- Desalination plant capacity and running hours;
- Waste water treatment plant capacity and running hours;
- Pumping systems and their capacity;
- Energy required for supplying DHW;
- Size of swimming pools;
- Occupancy and number of guests;
- Number and size of facilities such as restaurants, outlets, health centres, etc.

Figure 4-18 shows that the water consumption per guest-night varies in the years 2002 to 2006 between 0.6 and 1 cubic meter. Resort 1 had higher consumption rate in the earlier years which reduced down to ca. 0.80 m^3 from 2001 onwards. The year 2001 shows excessive values for Resorts 2 & 3 with no provided explanation.

Comparing those figures with those mentioned in Table 3-2 where the benchmarks for water consumptions in tropical and Mediterranean regions are mentioned, one can note that the water performance ranges from satisfactory to excellent based on tropical values while high to satisfactory based on Mediterranean values.

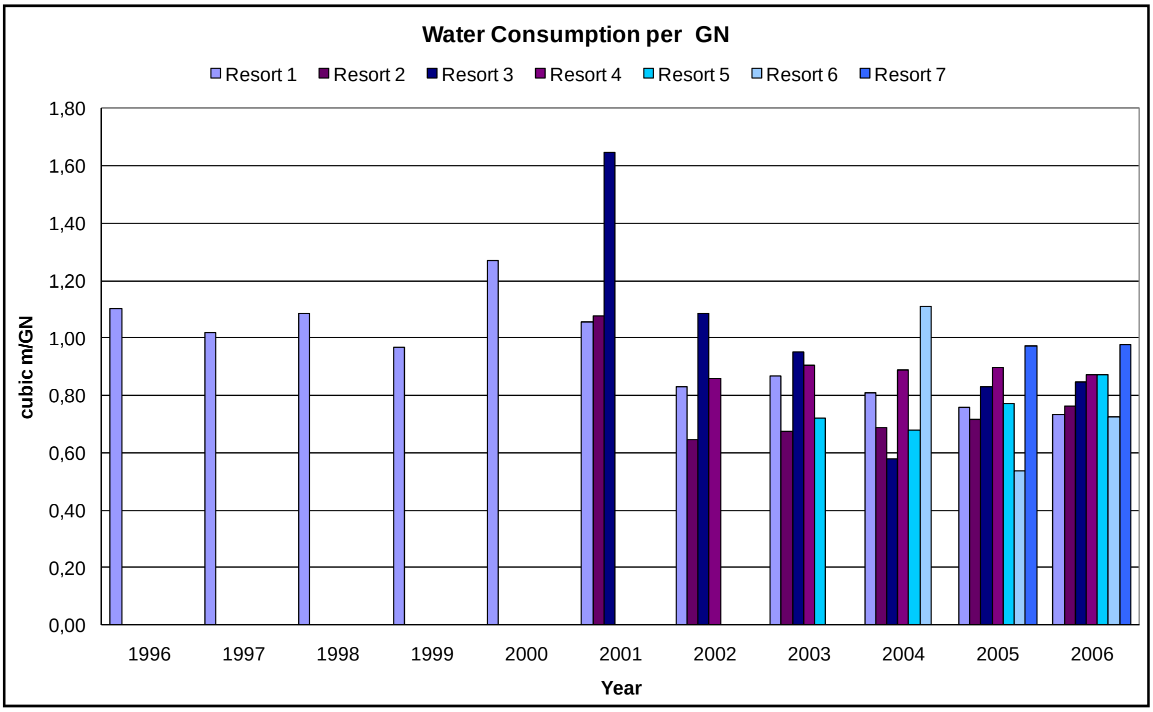

Figure 4-18: Average water consumption per guest-night at Sharm el Sheikh resorts

Figure 4-19 shows the total monthly consumption of water in 6 of the resorts. All resorts showed a steady consumption throughout the year except for Resort 5 which shows higher consumption in the last 3 months of the year. Again, no explanation was given for this increase.

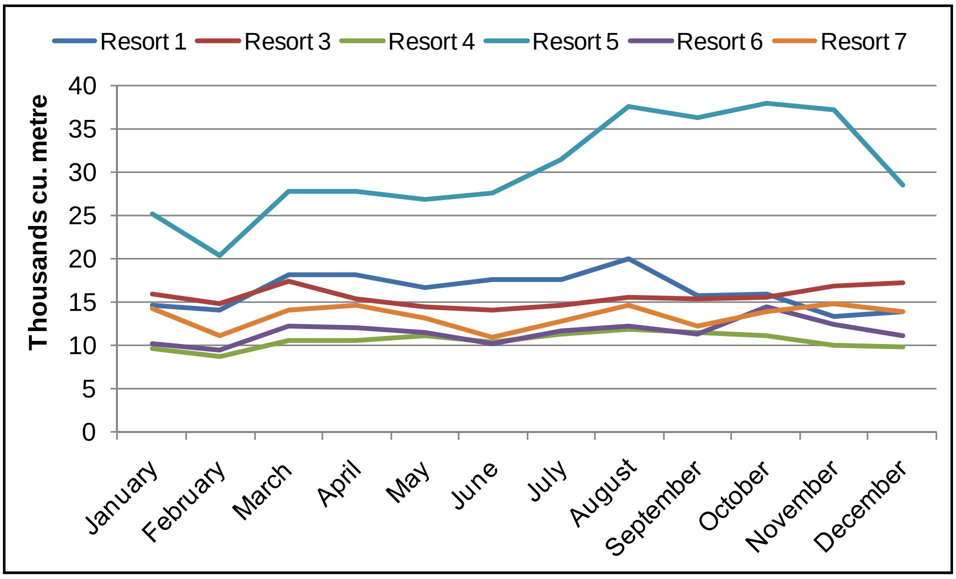

Figure 4-19: Monthly water consumption in 2006 at Sharm el Sheikh resorts

4.5.2.6 Occupancy versus consumption

In this section, the occupancy data is analysed against the consumption rates of energy and water. Figure 4-20 shows the water consumption pattern versus the occupancy rate while Figure 4-21 shows the total energy consumption expressed in monetary terms per guest-night (Euro/GN). In order to get an overview of the total energy consumption, the different types of energy: Electricity, fuel and LPG are converted to consumption costs by calculating the cost of each type of energy using a common base of unit price for all resorts. The prices of energy in 2007/2008 were 0.22 EGP/kWh (0.029 €/kWh), 1.00 EGP/kg (0.133 €/kg) and 0.5 EGP/litre (0.067 €/litre) for electricity, LPG and fuel respectively at Sharm el Sheikh. An exchange rate of 1 Euro = 7.5 EGP was used.

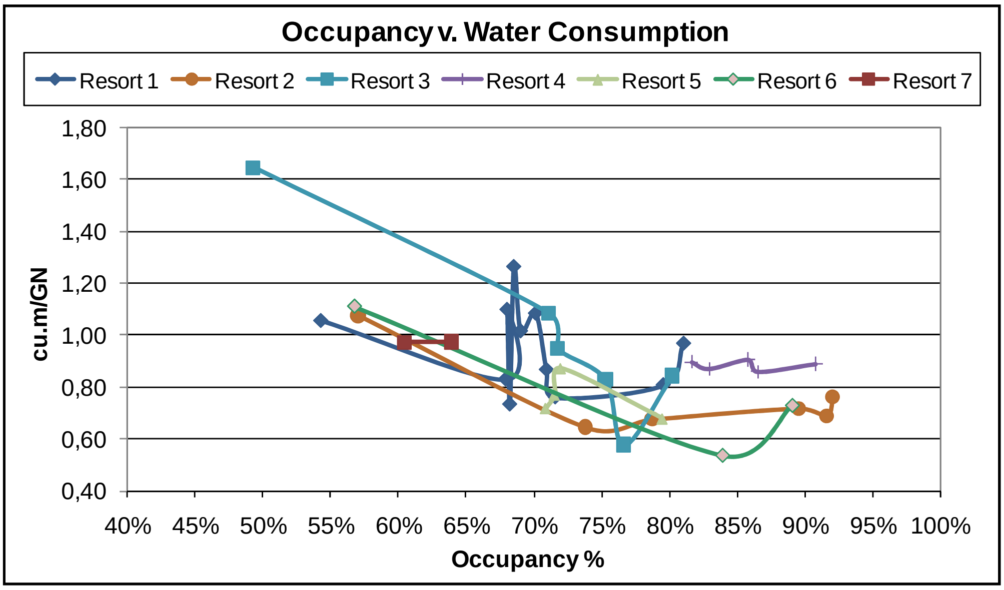

Figure 4-20: Occupancy versus water consumption expressed in cu. meter/GN at Sharm el Sheikh resorts

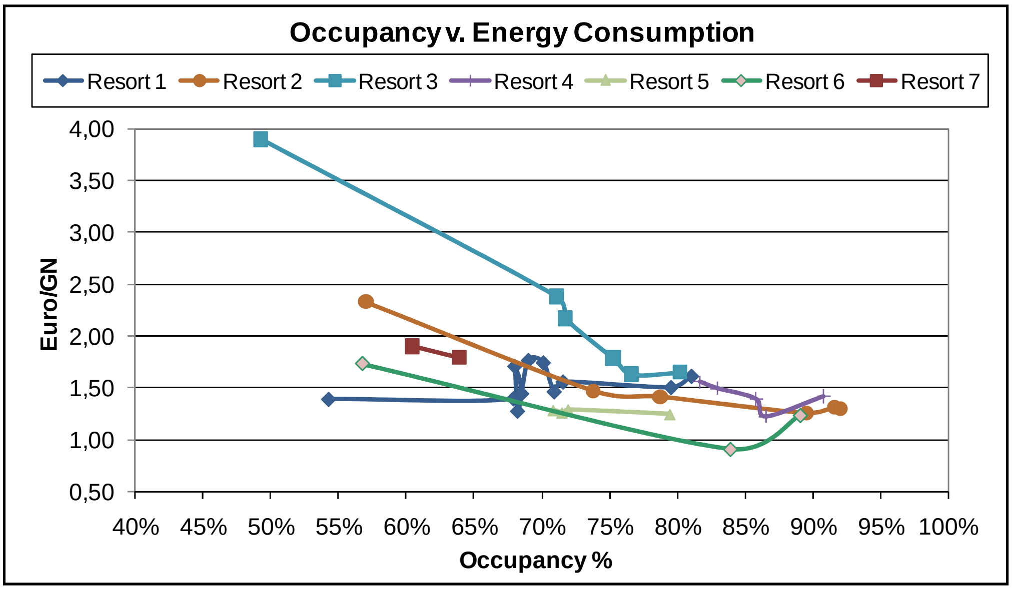

Figure 4-21: Occupancy versus total energy consumption expressed in Euro/GN at Sharm el Sheikh resorts

Although the consumption per guest-night decreases with the increase in occupancy, yet the relationship is not a straight-line. It is noticed that starting from an occupancy rate of 80% and above, the consumption rate per guest-night does not change greatly. The consumption intensity increases significantly when the occupancy rates fall below 70%. As a result, the author will assume an occupancy rate of 100% in the calculations and evaluation of different design alternatives in the next chapters.

4.5.3 Summary and discussion of energy consumption at Sharm el Sheikh resorts

The median values of the consumption rates for each resort are computed over the different years from 1996 to 2006 and used in Figure 4-22 to provide an overview of each resort's total energy consumption expressed in cost units. Based on the rates mentioned in the previous section 4.5.2.6, the total cost of energy consumption varies between 1.17 & 1.85 €/GN.

It is observed from the above mentioned detailed results that the consumption rate of Resort 5 lies within the same range of the other audited resorts which indicate having 835 GR, versus the other resorts having half of this GR capacity, does not have an obvious influence on the GN consumption.

It is also observed that Resort 3 always showed exceptional high consumption during the first years of its operation, especially in the year 2001. This could be contributed to the very low occupancy rate, barely reaching 50%, or it could have been due to management and operation problems during the first year. However, its consumption rates start to decrease over the years as they gained more experience.

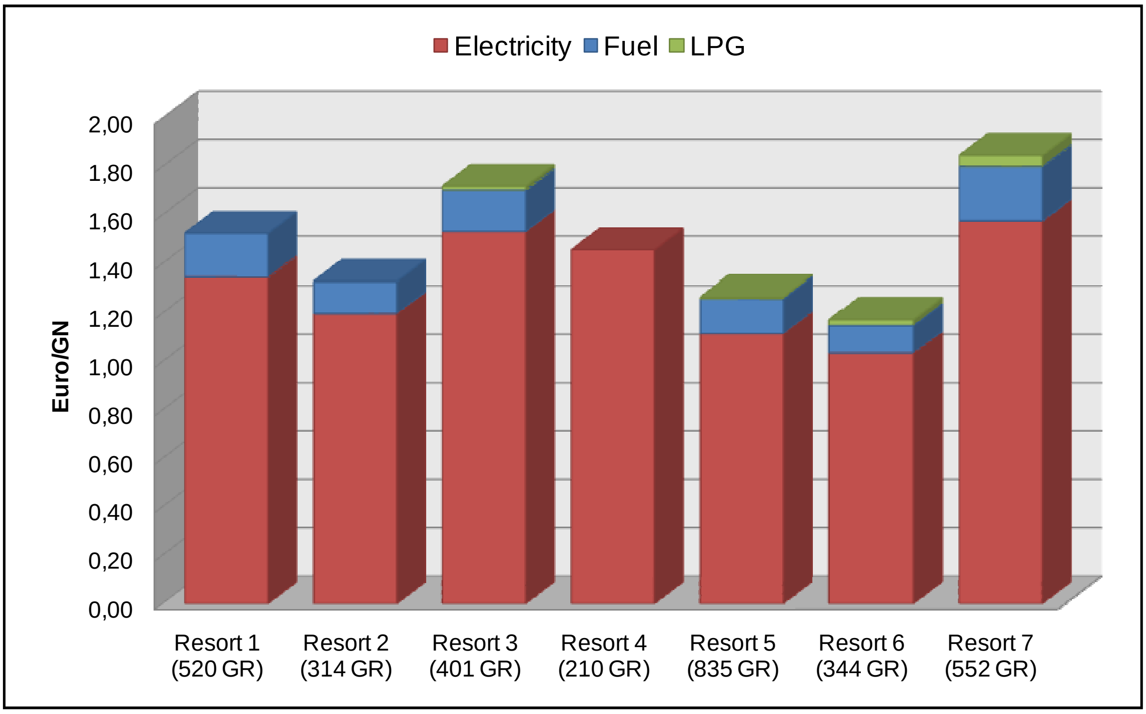

Figure 4-22: Summary of energy consumption for the audited resorts in Sharm el Sheikh expressed in EGP per guest-night

The results of the audit and analysis carried out on the five stars resorts in Sharm el Sheikh shows that their energy performance follows the same energy use patterns of other hotels worldwide and that their consumption rates are directly affected by occupancy and guest number as outlined earlier in the literature review in Chapter 3. The survey also showed that environmental practices are very low in Sharm el Sheikh.

5 Development of Solar Resort Design Alternatives

In this chapter, the author establishes the hypothesis of this study ‘Solar Resorts and Environmental Sustainability in Sharm el Sheikh’ as outlined in Figure 5-1. First, the author examines the design of a conventional design for a resort in Sharm el Sheikh which is used a basis for developing the design alternatives using the solar resort concept not only for Sharm el Sheikh but also for other regions with similar climate conditions. The results of the analysis carried out in the last chapter are used along with the design information of one of the seven investigated resorts. This step is necessary in understanding the energy flow in a resort and the underlying issues that should be considered during the development of the design alternatives. Resort 6 is chosen as the case study due to the availability of the design information in addition to the author’s own involvement from 2000 to 2004 as project manager in the development and implementation of this resort. The case study Resort 6 will be referred to as business-as-usual (B-a-U) case.

A value management exercise is carried out on the B-a-U case identifying opportunities for the solar design alternatives. The generated ideas are focused on energy production systems and carriers: heat and power. Energy efficiency is considered in the solar design alternatives; however, it is not in the scope of this thesis to deal with it in details. The approximate energy yield and distribution in the B-a-U case and proposed systems are worked out and the so-called renewable fraction is determined for the parts of electrical and thermal energy which can be covered by RETs.

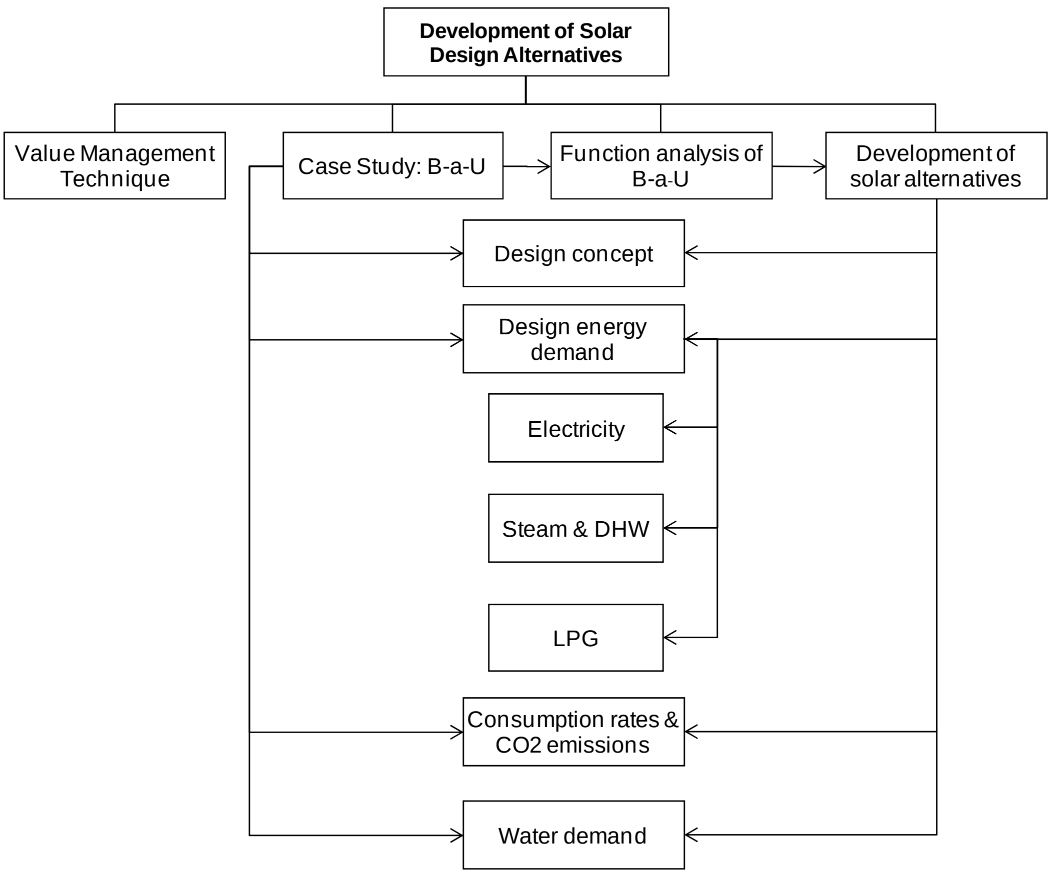

Figure 5-1: Outline of chapter 5

5.1 What is Value management?

Value Management (VM) is a proven management technique used to identify the alternative approaches for satisfying clients' requirements while lowering costs and enhancing value. It is often the case that: ambiguous objectives, misleading information, hasty decisions, lack of sufficient funds and resistance to change all result in poor value. Whereas, value is a ratio of quality and life-cycle cost (ICE, 1996).

VM helps in validating the stakeholders' expectations by achieving a balance between resources & performance throughout the project life. Figure 5-2 outlines the VM process, where function is defined as the intended operation of an item or service in its normally prescribed manner. The functions are analysed using 'Function Analysis Systems Technique' known as FAST diagrams. The functions of a project or process are defined using a 'verb noun' format. Each identified function is subjected to three questions leading to the expansion of the process. The three questions are: Why do you *'verb noun'*? How do you *'verb noun'*? When do you *'verb noun'*? The first question 'why' leads to a higher-level function, and the second question 'how' leads to a lower-level function while the third question 'when' may lead to the identification of new functions and their order or relationships. The answer to each of these questions will be either another *'verb noun'* or one of the previously identified functions. The outcome of this process is presented in Figure 5-3.

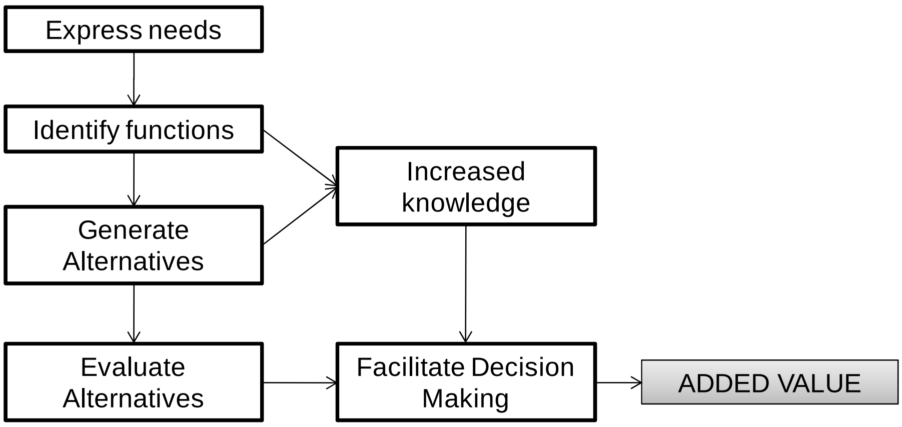

Figure 5-2: Value Management process

VM is optimally applied at the earliest stages of any project. Figure 5-4 illustrates the project development phases of any project and that the highest costs occur during the operation phase of a project while the minimum cost occurs during the first planning stages. The influence to introduce any changes, value or to economise in a project decreases with time along the project's life. The best chance to test new ideas and design concepts is right at the start of the planning phase of the project.

The VM process explained above is used in the next sections in analysing the B-a-U case and developing design alternatives using RET.

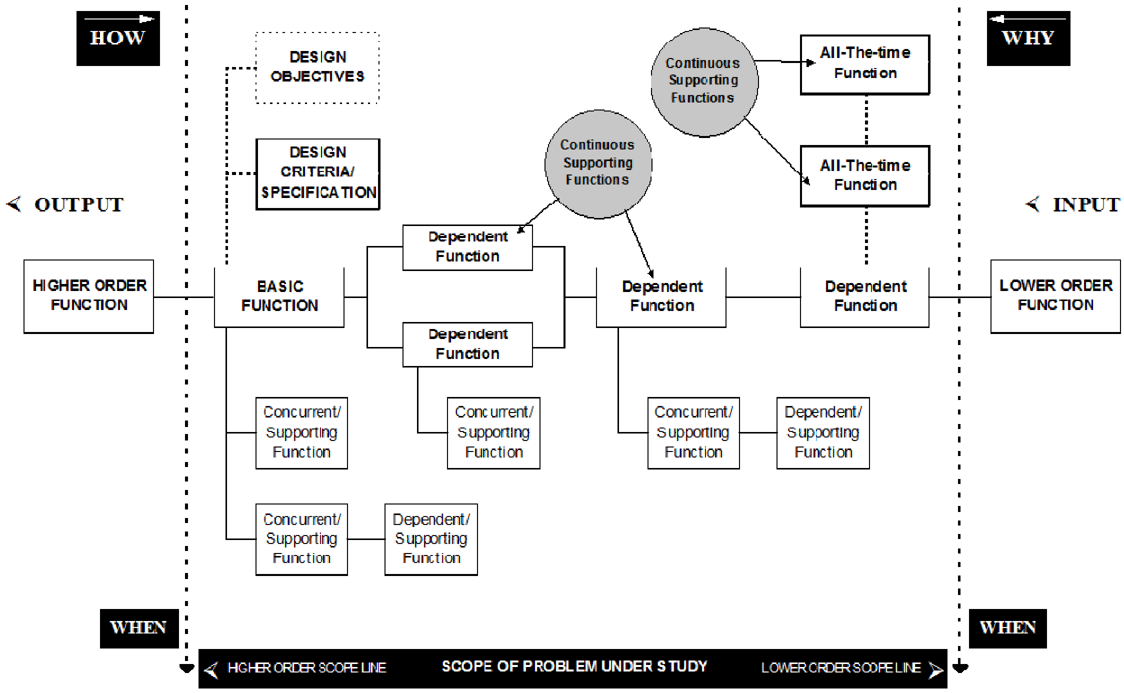

Figure 5-3: A Typical FAST diagram (Georgei, 1998)

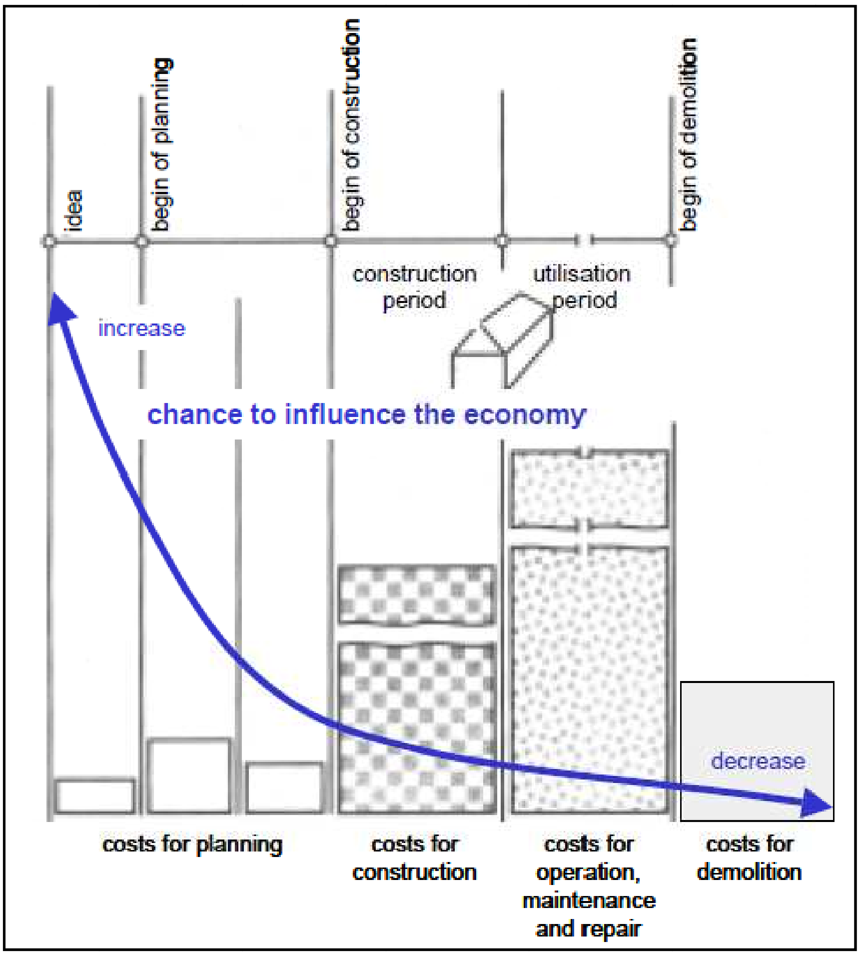

Figure 5-4: Cost blocks over the entire cycle and chance to influence the project's economy (K. Herzog & Graubner, 2002)

5.2 Case Study: Business-as-Usual

Resort 6 out of the 7 audited resorts in Sharm el Sheikh is taken as the B-a-U case representing most of the common design practices and design criteria in Sharm El-Sheikh. The resort consisting of 344 guest rooms was commissioned into operation in 2004. It is owned and developed by a property development company while the resort operation is managed by one of international hotel management companies active in Egypt.

The resort covers a total area of m^2 150,000 of which 20% are occupied by buildings. The remaining land is landscape areas distributed among green areas, swimming pools, and other outdoor entertainment facilities. Figure 5-5 illustrates the main functional components required in the resort.

5.2.1 B-a-U design concept

The project design packages were assigned to a group of consultants with different specializations where they were managed and co-ordinated by the leading architect and owner. The architectural concept adopted in this resort is the typical owner's approach towards maximizing number of guest rooms and public facilities with the minimum costs. No particular attention was given to the orientation and design of the buildings with respect to the prevailing climatic conditions. Hence, heat gain was not minimized through the application of solar architecture and energy efficiency measures. For instance, some of the buildings' main characteristics are:

- The external walls are made out of a single layer of typical red bricks without any kind of thermal insulation.
- Tinted single glass was used for all the glazing and window façades.
- Large glass façade areas were implemented without any shading concept to prevent the penetration of high amounts of sun radiation during the peak operation hours of the air conditioning system. Avoiding north south orientation was not considered in areas having large glass façades such as the lobby and reception areas.

Similarly, the electro-mechanical design was based on meeting the owner's main objective of minimum investment costs, without any consideration for operation & maintenance (O&M) costs and neither with any concerns for environmental impacts. The energy production system chosen for the B-a-U case depends on supplying the resort with power from Sharm el Sheikh's main grid required mainly for lighting, air-conditioning, desalination, kitchen and laundry equipment in addition to thermal energy supplied by steam boilers and LPG which are needed for DHW, the laundry and kitchen. Figure 5-6 depicts the different elements of the B-a-U energy production system.

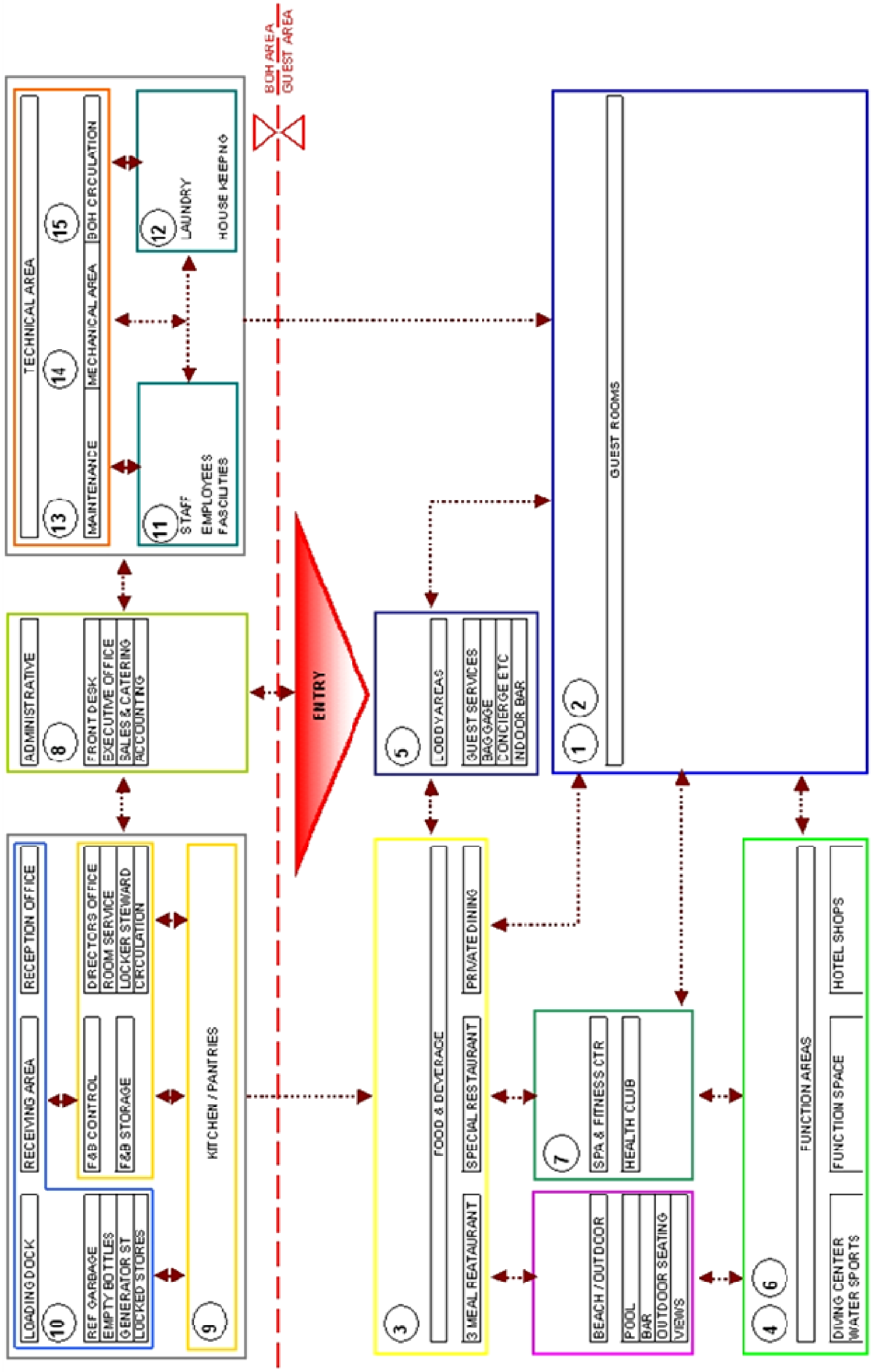

Figure 5-5: Typical functional and operational requirements for a resort

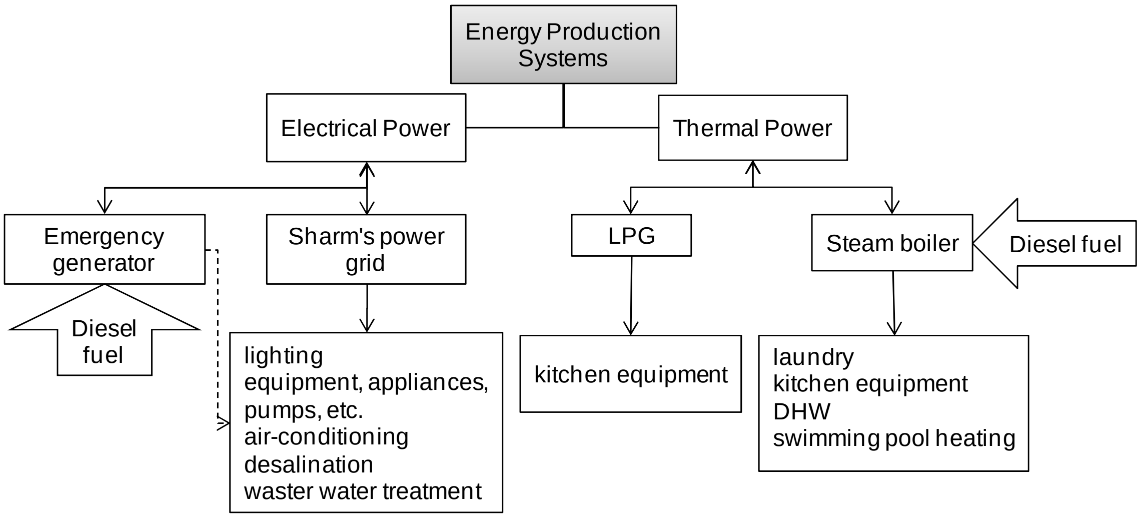

Figure 5-6: Energy production systems in Business-as-Usual case

5.2.2 B-a-U design energy demand

This section outlines the energy demand for the B-a-U case. The design values are determined and compared to the actual consumption data analysed in chapter 4. The author chose the year 2006 as a basis for comparison since Resort 6 shows the highest occupancy rate of 89% in 2006. Moreover, the resort was commissioned in 2004 and, accordingly, the year 2006 reflects a mature state of the resort's operation after experimenting and establishing an efficient daily operation system in the first year.

5.2.2.1 B-a-U electricity demand

Three medium to low voltage transformers with a total capacity of 2.7 MW were selected to meet the resort's energy demand. Additionally, a 1 MW diesel generator is installed for emergency cases and power cuts.

The peak electric demand was designed to be 2.6 MW and the total daily consumption per ca. 30.6 MWh based on 100% occupancy. The following Table 5-1 demonstrates the breakdown of design electric loads and equivalent hours of operation per day. The original detailed version of this table is attached in the appendices.

The design value of the total daily power demand is compared to the actual consumption of Resort 6. In the year 2006 and at an average occupancy of 89%, the average daily consumptions in the months of August & September were 29.25 & 26.071 MWh respectively. Accordingly, one can state that the design value of 30.6 MWh/day correlates with the actual consumption bearing in mind that in August and September, the energy consumption increases as a result of higher cooling demand. Establishing confidence in design values versus actual consumption, the author means to use the design values of Table 5-1 as a basis for the development of the design alternatives.

Assuming an average GtR ratio of 1.85 and occupancy rate of 100% and considering the designed daily power demand of 30.6 MWh, the power consumption per guest-night is calculated 48.1 kWh and is taken as the design value for the B-a-U case.

Pos.	Item	Utility Description	Running Time hr	Peak load kW	Energy kWh/d
A	Main building				
A-1		AC for complete building: 2x90 RT chillers + 143 FCU + 17 AHU	16	606.528	9,704.448
A-2		Public areas & admin: lighting, appliances and equipment	6.25	68.34	427.36
A-3		Guest rooms (130 GR): lighting, TV, mini bar, etc.	3.013	36.24	109.2
B	Restaurants & shops building				
B-1		AC for complete building: 2x190 RT chillers + 33 FCU + 6 AHU	12	547.776	6,573.312
B-2		Public areas: lighting, appliances and equipment	6.88	60.21	414.14
B-3		Main kitchen: lighting, equip-ment, etc.	8.1	185	1,498
C	Laundry: lighting, equipment		4.33	82.25	356
D	Cold rooms		16	10.5	168
E	Swimming pools & fountains				
E-1		Pumping rooms	18.79	70.25	1,320
E-2		Lighting	8	12.95	103.6
F	Cluster blocks (140 GR)				
F-1		AC: split units	10	243	2,430
F-2		Lighting, TV, mini-bar, etc.	2.26	61.81	139.68
G	Staff building				
G-1		AC: split units	10	67.5	675
G-2		Lighting, TV, mini-bar, etc.	2.4	12.15	29.19
H	Desalination plant		24	115	2,760
I	Waste water treatment plant		16	30	480
J	Steam Boilers		16	24.36	389.76
K	Landscape lighting		8	333	2,664
L	Other: gym, health club, booster pumps, elevator, etc...		4.94	63.72	314.94
Total Power Demand				**2.6 MW**	**30.6 MWh/d**

Table 5-1: Energy daily load profile for Business-as-Usual case

The main power consumers of the B-a-U resort are illustrated in Figure 5-7. It is observed that the air conditioning, RO desalination and kitchen equipment are the highest consumers requiring a load of 1,464 kW, 115 kW and 192.5 kW respectively. The air-conditioning system constitutes a share of 59% of the peak load and 61% of the daily consumption. The second high consumer is the RO desalination plant where it constitutes 4% of the peak load and 9% of the daily consumption. The third high consumer is the kitchen equipment representing 5% of the peak load and 7% of the daily consumption. The remaining load is distributed on other diverse services and equipment of the resort.

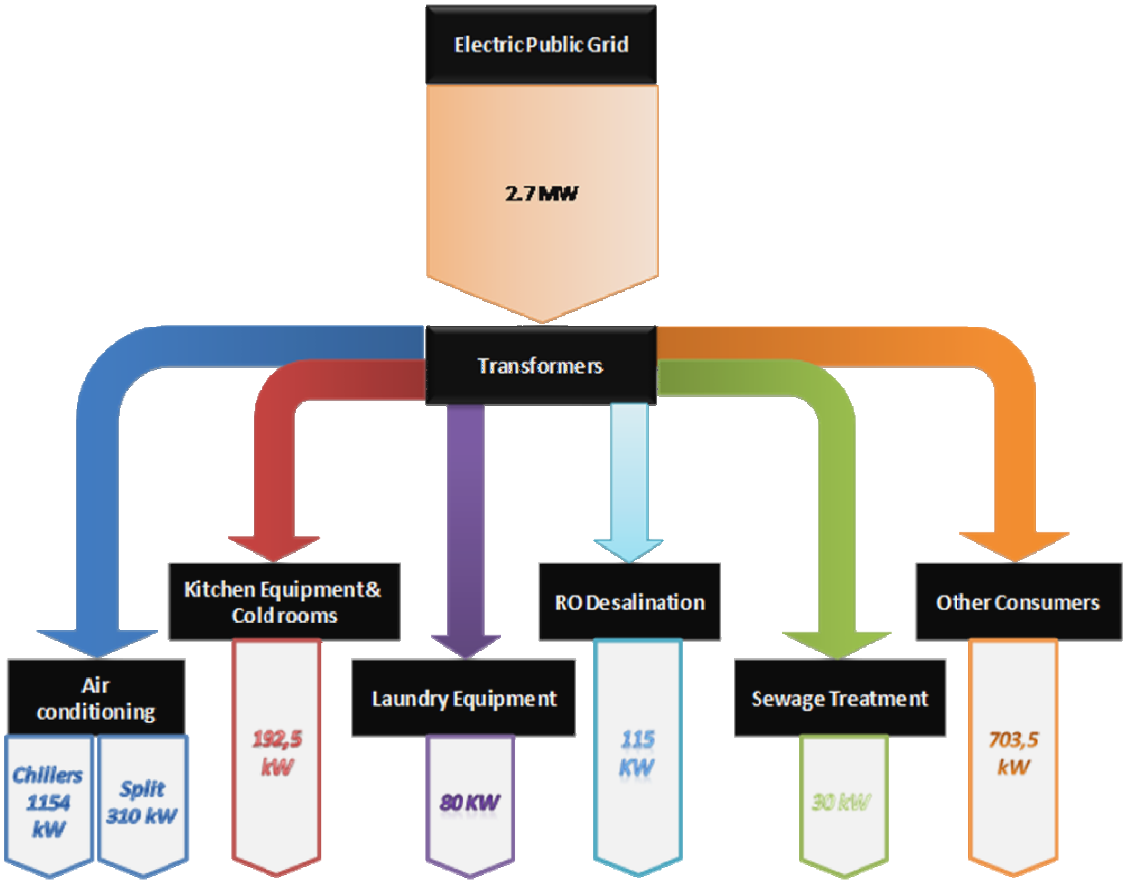

Figure 5-7: Distribution of power load to the main consumers in the B-a-U resort

According to the technical staff of the resort, the peak demand usually occurs during the day between 12 and 8 pm where it is likely caused by the elevated air conditioning load resulting from the higher temperatures in addition to the kitchen and desalination plant operating at full load during the day to cover the needs of guests.

5.2.2.2 B-a-U Steam & DHW demands

Two steam boilers are used to cover the resort's demand of steam and DHW; each boiler has a capacity of 3 ton/hr, equivalent to 2050 $kW_{th,}$ & an efficiency of 80%. The main consumers of the thermal energy produced are DHW for the complete resort, steam for the laundry equipment and heating for the swimming pool (Figure 5-8). This thermal energy load can be covered by the output of one boiler; however, a second boiler is used to acts as a backup in case of excessive loads or breakdown of first boiler.

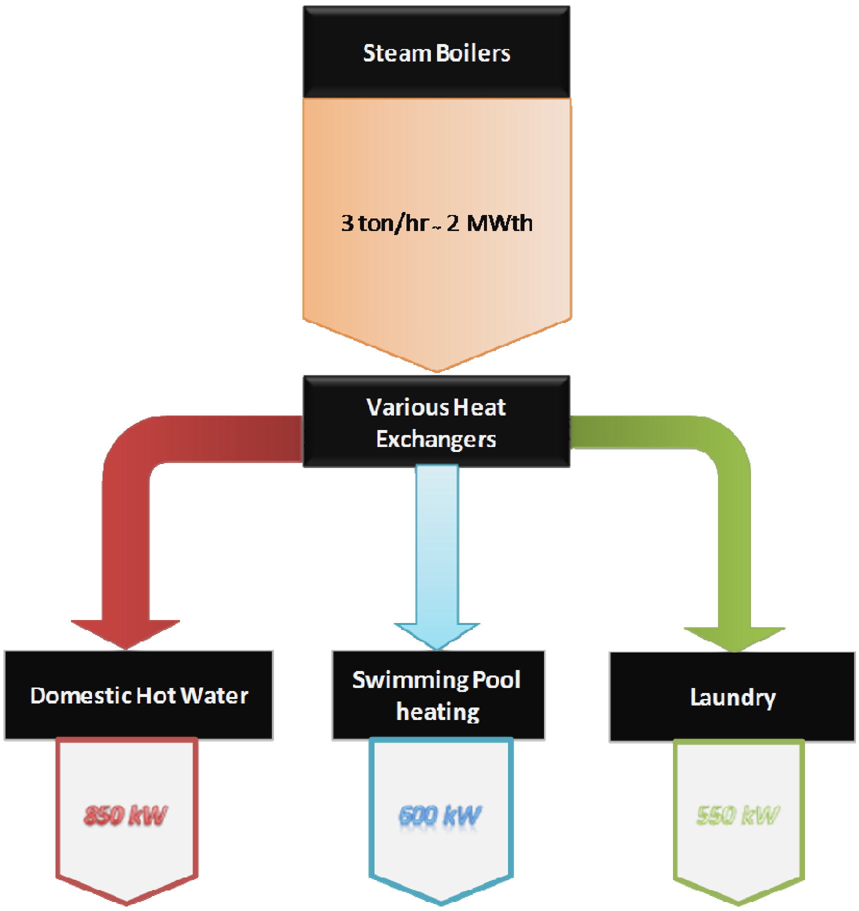

Figure 5-8: Distribution of thermal energy to the main consumers in the B-a-U resort

Assuming a full load operation of 8 hours per day and at a fuel consumption rate of 210 litre/hr, the estimated daily and annual fuel consumption are 1680 & 613,200 litres respectively. The actual annual consumption for Resort 6 in 2006 is 483,100 litres which is lower than the estimated design value by ca. 20%. Studying the figures analysed in chapter 4, it was noted that Resort 6 was one of the lowest fuel consumers among the six resorts using fuel. In order to use a conservative figure, the author decided to take median value of guest-night consumption of five audited resorts (Resorts 1, 2, 3, 5 & 6); Resort 7 was excluded due to its high values. Accordingly, with median value of 2.43 litre/guest-night, GtR ratio of 1.85 and an occupancy rate of 100%, the daily fuel consumption is calculated to be 1546 litre and is considered the design value for the B-a-U case. This value is also nearly 8 % less than the original design value provided by Resort 6.

5.2.2.3 B-a-U LPG demand

LPG is used to operate part of the kitchens equipment such as ovens. The total thermal power required for the gas equipment is designed 273.7 kW. Assuming 8 hours of full load operation, the designed daily consumption is computed to be 2189.6 kWh (159.24 kg) and the total annual consumption 58,122 kg of LPG.

The actual annual consumption of Resort 6 in 2006 was 36,600 kg with an average daily consumption ranging from 81.33 to 162.67 kg. The total actual annual consumption is lower by ca. 37% than the designed value. As mentioned in Chapter 4, the LPG consumption depends on the percentage of gas equipment installed and, hence, the author could not use the consumption of the other resorts, however, the median of guest-night consumption for Resort 6 over 3 years is 0.2 kg and this will be the value taken for the B-a-U case yielding a total annual value of 46,457 kg based on a GtR ratio of 1.85 and an occupancy of 100%.

5.2.3 B-a-U overall consumption and CO_2 emissions

Three different types of energy resources were considered in the B-a-U case. However, one needs to identify the influence of each type on the operation cost as well as on the CO_2 emissions in order to establish the impact factor of each type and prioritise which areas need to be utmost addressed.

	Electricity (kWh)	**Fuel (Litre)**	**LPG (Kg)**	
Consumption per guest-night	48.1	2.43	0.2	
Total annual consumption	11,172,957	564,455	46,457	**Total**
CO_2 emissions per guest-night (kg)	28.38	6.39	0.58	**35.35**
Total annual CO_2 emissions (tonnes)	6,592	1,485	136	**8,212**

Table 5-2: B-a-U energy consumptions and CO_2 emissions

Table 5-2 provides a summary of the guest-night and annual consumptions for each of the energy resources. The energy costs mentioned in the above table are based on the latest energy bills in Sharm and an exchange rate of 1 Euro = 7.5 EGP. The carbon conversion values for LPG and fuel are 1.495 $kgCO_2$/litre (2.92 $kgCO_2$/kg)and 2.63 $kgCO_2$/litre respectively (Trust, 2009). On the other hand, the carbon conversion value for electricity differs from one country to the other depending on the percentage of fossil resources used in generating power. In the case of Egypt, simulation show that this factor ranges from, 0.58 to 0.61 $kgCO_2$/kWh (Ringuis, et al., 2002). For the purpose of this thesis, a value of 0.59 is taken in the calculations of CO_2 emissions.

It can be observed that electricity has the greatest influence on the energy performance of the resort. Figure 5-9 shows that electricity has a share of 85% in the operation cost and is also the main contributor in CO_2 emissions. LPG plays a very small role in the energy performance of the B-a-U case with respect to the electricity and fuel.

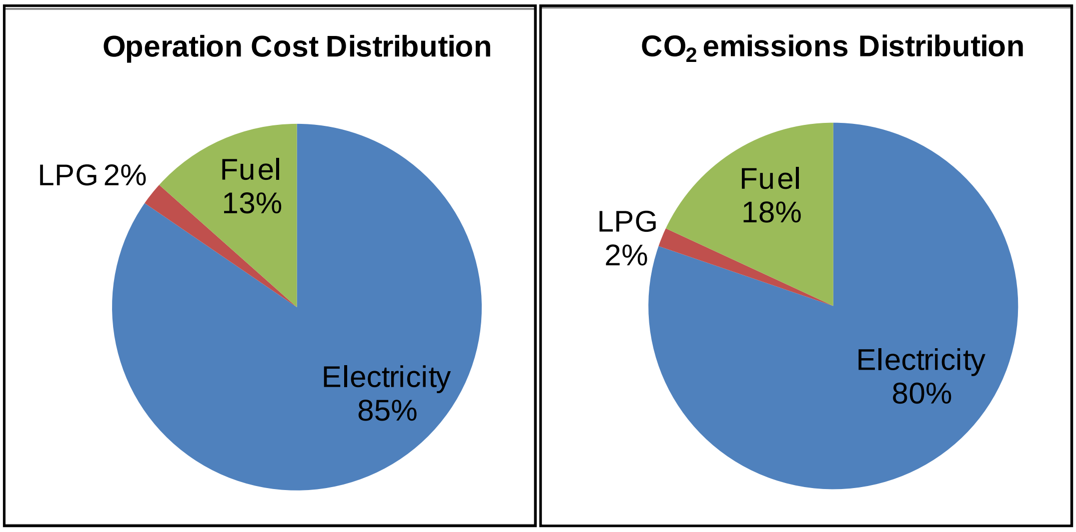

Figure 5-9: Contribution of the energy resources in operation costs and CO_2 emissions

5.2.4 B-a-U design water demand

A total water demand of 500 m^3/day is designed to cover the requirements of the resort. This water is provided through an RO desalination plant and is used for domestic purposes such as washing, cleaning, bathrooms, kitchen use and swimming pools. Drinking water is not included in this amount as bottled mineral water is provided separately. The average actual consumption per guest-night according to the consumption in 2006 is 0.73 m^3, yielding a total demand of 462 m^3/day based on 100% occupancy and 1.85 GtR. This value correlates well with the design value indicating that the produced water is almost entirely consumed and is accordingly adopted in the B-a-U case.

The waste water treatment plant is designed for a capacity of 400 m^3/day. The design value is based on treating 80% of the capacity of the desalination plant assuming 20% losses in circulation leakages and evaporation. The treated waste water is then used in irrigation of the landscape.

Although, the study is concerned with the energy performance of the resort, nevertheless, the amount of water consumed and, thus, the capacities of both the desalination and waste water treatment plants have an indirect influence on the energy consumption.

5.3 Function Analysis of case study

In this section, the author carries out a function analysis based on the design concept and values of the B-a-U case with regards to the resort's energy production system. The aim here is to avoid jumping into solutions but rather to identify the functions first. For example, in common practice the electrical demand of a resort would be calculated including the air-conditioning system and, hence, already assuming a solution using power operated systems without considering other options such as seawater cooling, solar cooling, cooling using heat recovery systems or any other systems.

The needs and requirements identified in the B-a-U case are transformed into a function tree. The top of the tree will start with the "raison d'être" of the entire project, which in our case is developing a sustainable resort. This is then broken down into sub-objectives elements

(Figure 5-10). The 'HOW' question leads to lower levels of the functions and the question 'WHY' leads to higher levels. In other words, the right side of the diagram resembles the inputs for developing a sustainable while the left side is the output produced.

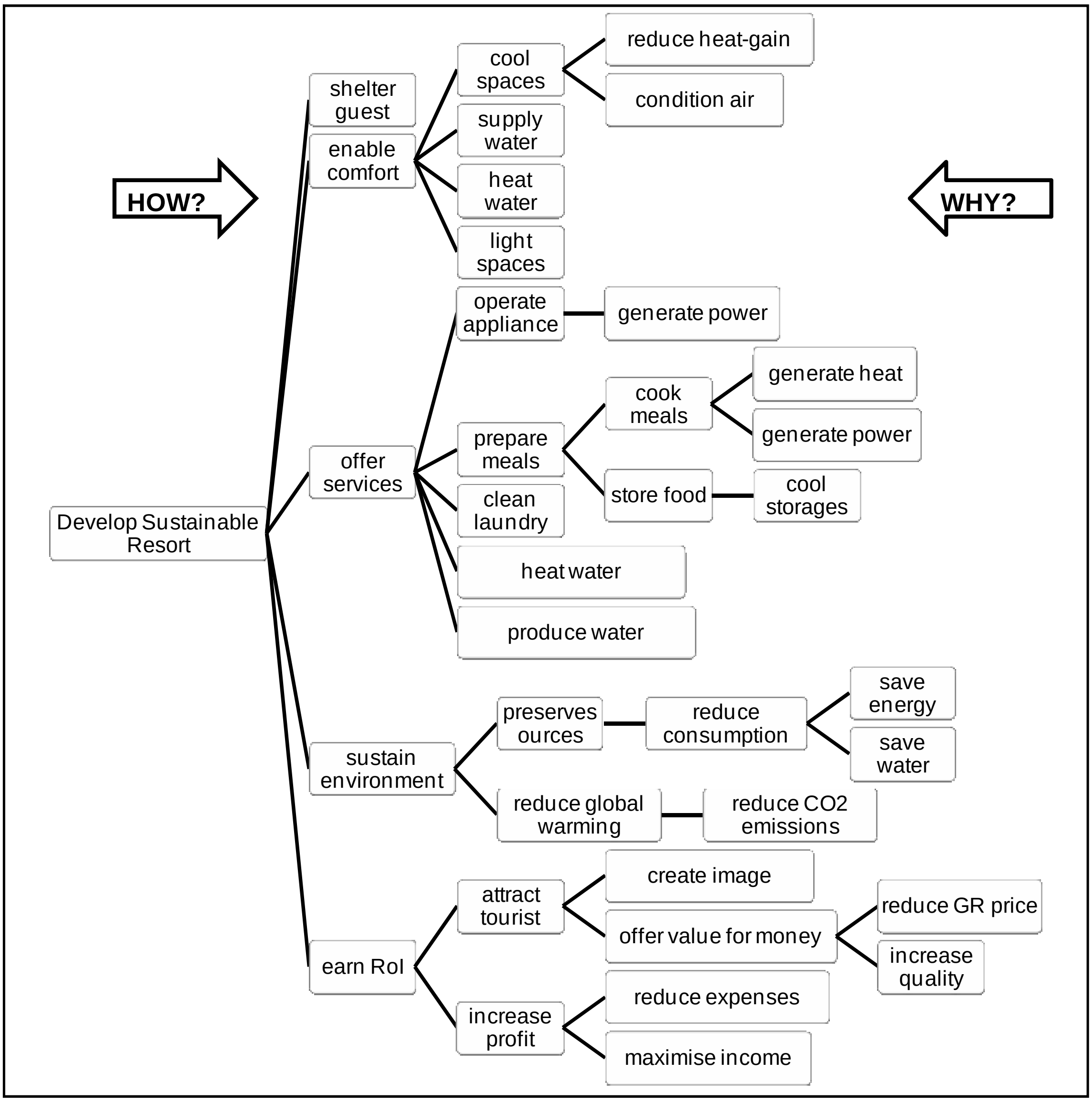

Figure 5-10: FAST diagram for developing a sustainable resort

At this stage the costs are ignored as they may hinder generation of ideas and they will be considered and evaluated at a later stage after the development of design alternatives. The focus here is on three specific functions and their lower levels: enable comfort, offer services and sustain environment. It can be noted that one common factor in those three functions and their breakdown is energy in its different forms. Although the return on investment (RoI) is important for the owner, this function among all cost issues are addressed later during the economical evaluation of the alternatives.

A brainstorming session is conducted in order to identify broad approaches to achieve the functions listed on the FAST diagram in Figure 5-10. The ideas are first evaluated in terms of technical feasibility with respect to location and climatic conditions and are grouped as follows:

- Power generation:
    - Wind energy
    - Solar PV
    - CSP
    - Geothermal
    - Biomass
    - Wave
    - Tidal
- Hot water/steam generation:
    - Solar thermal collectors
    - CSP
    - Biomass
    - Geothermal
- Cooling generation:
    - Solar Photovoltaic (power)
    - Solar thermal collectors
    - CSP (power or thermal)
    - Deep seawater cooling
    - Biomass
    - Geothermal
- Desalination:
    - Solar Photovoltaic
    - CSP Power (power or thermal)
    - Solar thermal collectors
    - Biomass
    - Geothermal
- Reduce consumption through proven energy efficiency measures including water.

The following idea are rejected and not further considered for this case study:

- Biomass: there is no biomass available in the region of the Sharm El Sheikh. One of the high potentials for biomass in Egypt is the rice husk; however, this is produced in the Delta region of Egypt, located more than 1000 km away.
- Wave and tidal: these RET types are still at research stage and are not yet commercially developed for individual applications as in the case of a resort.
- Geothermal: the literature indicates availability of a geothermal reservoir 100 km North of Sharm el Sheikh (El-Qady, 2006). However, there is no available information about availability of geothermal energy within the boundaries of Sharm el Sheikh. Moreover, this option is not fully explored, in terms of small to medium scale applications, in comparison to solar and wind energy.
- Deep seawater cooling: the environmental authority of the Red Sea restricts any sort of off-shore construction works along the shore of the Red Sea due to the high risk involved in damaging the coral reefs.

5.4 Development of solar design alternatives

In this step, the ideas technically approved in the previous step re developed into alternative solutions meeting the complete energy demand of the resort. The main criterion is to cover the resort’s energy demand 24 hours and all year round. Based on the values of operation costs and CO_2 emissions mentioned in section 5.2.3, the author will neglect LPG due to its minor contribution in the energy performance of the resort and will rather consider electricity, steam and DHW in the development of the design alternatives. The LPG part will remain the same in all alternatives based on the figures of the B-a-U case. Accordingly, the design alternatives are developed into three groups:

- Electrical energy demand:
  - WECS
  - PV
  - WECS and PV
- Electrical and thermal energy demands
- Cogeneration using CSP (electricity and cooling)

5.4.1 Water demand for solar alternatives

The B-a-U design value of 0.73 m^3 per guest-night is compared to the benchmarks mentioned previously in Table 3-2. Although this consumption rate is considered excellent being below 0.90 m^3/guest-night based on the tropical region benchmark, there still might be opportunity to save on water consumption. Therefore, a target of 15% reduction is set and is to be achieved through the introduction of additional efficiency measures. This reduction would result in an average consumption of 0.62 m^3/guest-night, requiring a desalination plant of 400 m^3/day capacity. A waste water treatment plant with a capacity of 320 m3/day is accordingly used. This decrease in capacities is expected to lead to lower energy loads.

5.4.2 Alternative 1

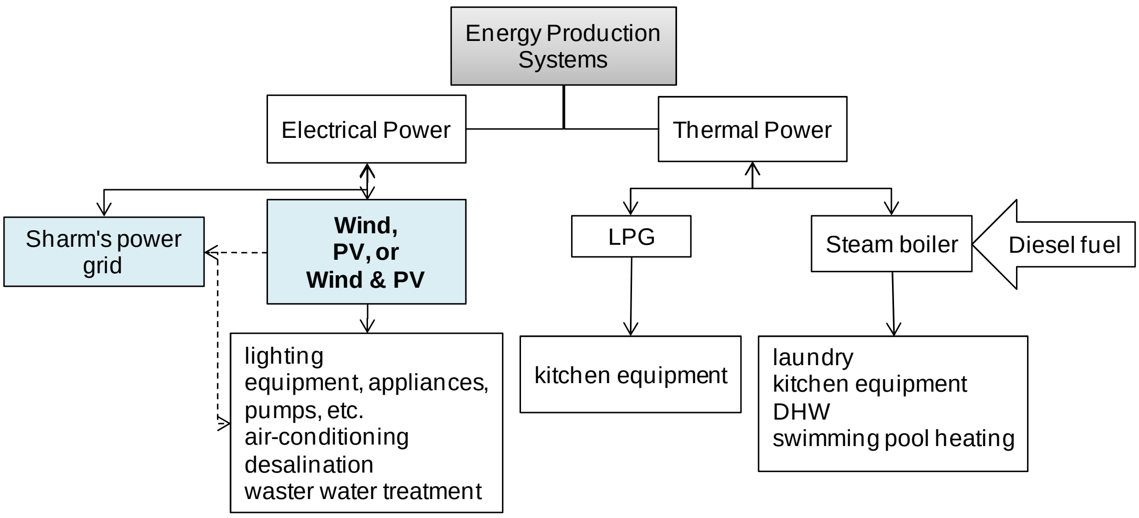

Figure 5-11: Energy production systems for Alternative 1

Alternative 1 is based on the same energy production system of the B-a-U case except for the source of electrical power (Figure 5-11). Three options are considered: WECS, PV and hybrid WECS & PV. Sharm el Sheikh's grid is used as a backup in case of peak loads or shortage in supply by the RET. A minimum renewable fraction of 40% is set for the three options forming a common basis for comparing the three options. No changes are introduced to the thermal power resources with respect to the B-a-U case.

5.4.2.1 Electricity demand for Alternative 1

The author assumes that by introducing energy efficiency measures, the electricity consumption will decrease by 30% based on the results of to several case studies mentioned by (REST). As mentioned earlier in this thesis, it is not within the scope of this thesis to discuss energy efficiency measures in details. The following are some of the proposed measures but not limited to:

- Reduced heat gain resulting solar architecture concepts which will, eventually, lead to less cooling demand.
- More efficient equipment and appliances in guest rooms
- Energy saving operation policy such switching off of TV instead of ‘stand-by’ status.
- Water saving policy such as encouraging guests to reduce unnecessary laundry.
- Smaller desalination plant, waste water treatment plant and boilers resulting from savings in water consumption.
- Solar lamps used for landscape lighting.

The 30% reduction in the energy consumption of the B-a-U case will lead to the following new energy demand profile is:

- Peak load of 1.82 MW
- Daily consumption of 21.42 MWh
- Average guest-night consumption of 33.66 kWh which is still 28% higher compared to the guest-night consumption in Cyprus indicated in Table 3-3.

Due to lack of hourly consumption data, the author could not compute the electricity load profile for 24 hours of a typical day at any of the resorts investigated in Sharm-El-Sheikh. This kind of information is required for the simulation of the RET. For that reason, the author used the daily load profiles of two resorts having similar operation conditions as the resorts in Sharm el Sheikh in terms of resort classification, climate and air-conditioning system. The first resort is located in a tropical area where air-conditioning is one of the highest consumers (Georgei, Krueger, & Henning, 2009), while the second resort is located in the subtropical region of Australia (Dalton, et al., 2008). Based on both profiles, the author estimated a daily load profile for Alternative 1 using the new energy demand profile (Figure 5-12). Consequently, the energy profile for Alternative 1 has a peak period from noon to evening which concurs with the information presented in chapter 4. During the night, very low activities occur and with lower cooling demands, the energy consumption drops to minimal. This estimated profile for Alternative 1, represents a typical summer day when full load of air conditioning is required and is accordingly used in developing the design of Alternative 1 and is used as input for the Homer simulation software.

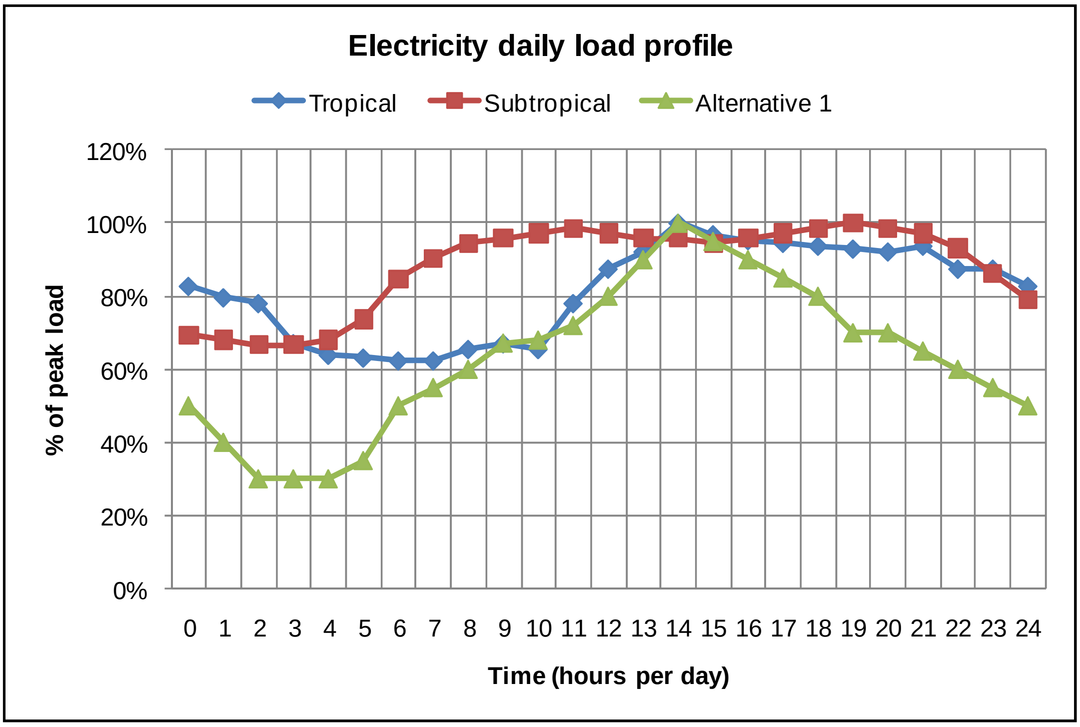

Figure 5-12: Estimated electricity daily load profiles for Alternative 1 based on two actual resorts

5.4.2.2 Electricity Resources for Alternative 1

In this section, the type and size of the proposed RET are determined using the HOMER software. The model is provided with inputs, which describe the energy demand, technology options, component costs, and resource availability. In order to determine the optimal configuration, different system configurations or combinations of components are simulated. HOMER simulates the operation of a system by making energy balance calculations for each of the 8,760 hours in a year. For each hour, HOMER compares the electric and thermal demand in the hour to the energy that the system can supply in that hour, and calculates the flows of energy to and from each component of the system.

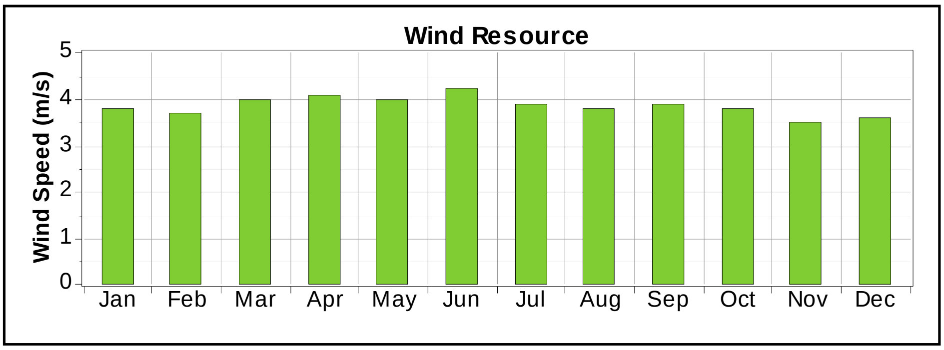

Figure 5-13: Average monthly wind speed in m/s in Sharm el Sheikh (NASA, 2010).

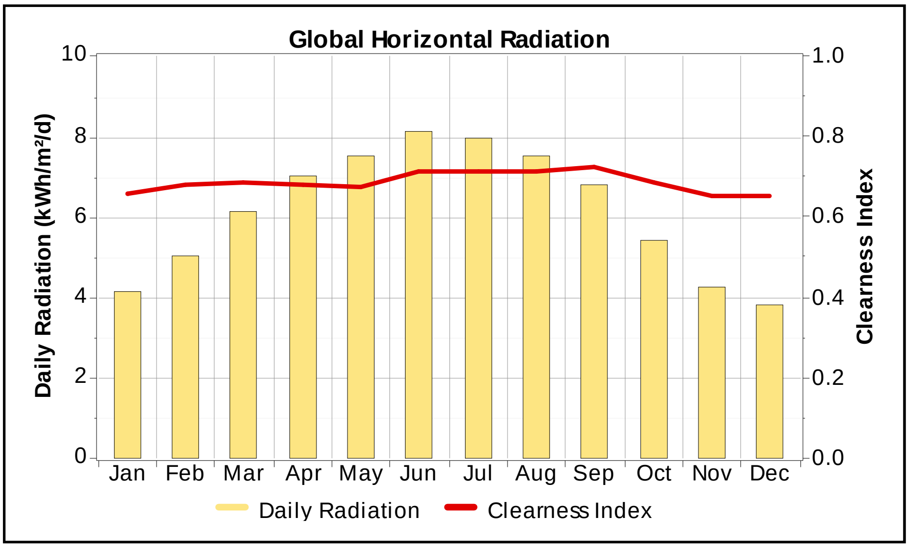

Figure 5-14: Average monthly solar irradiation kWh/m^2/day in Sharm El-Sheikh (NASA, 2010).

Figure 5-13 & Figure 5-14 show the data of the wind speed and solar irradiation, respectively, used as input in the simulation software. The results of the HOMER simulations are as follows:

a. **Wind:** in this option, Alternative 1-a, only WECS is used and any shortage in power supply through wind energy is compensated by the grid. It is also possible to feed-in any excess power generated by the WECS into the grid. HOMER was used to simulate the daily electricity load profile against the power generated through the WECS. Several configurations are simulated by the software and the optimal configuration is determined and presented in Table 5-3.

System	**Description**	**Electrical Production (kWh/yr)**	**Fraction**
Wind	7 x 330 kW Enercon E33	3,552,798	41%
Grid purchase	2 x 1 MW transformers	5,206,975	59%
Total		**8,759,773**	**100%**
Primary load (demand)		8,077,447	100%
Excess load		682,326	8%
Unmet load		0.00	0%

Table 5-3: System configuration and simulation results by HOMER for Alternative 1-a

It is worth mentioning that in case of Sharm el Sheikh, wind is not high enough as in other areas located in the Red Sea region. For example, in Hurghada and Marsa Alam, the average wind speed is high reaching a higher renewable fraction in comparison to Sharm el Sheikh. Figure 5-15 depicts the electricity load profile for a typical day in

August plotted against the power produced by WECS as well as the additional power supplied by the grid to meet the energy demand throughout the day. The WECS chosen by Homer is referred to Enercon E33 in the model. The monthly average electric production is illustrated in Figure 5-16 showing the proportion of wind energy versus the power supplied by the grid.

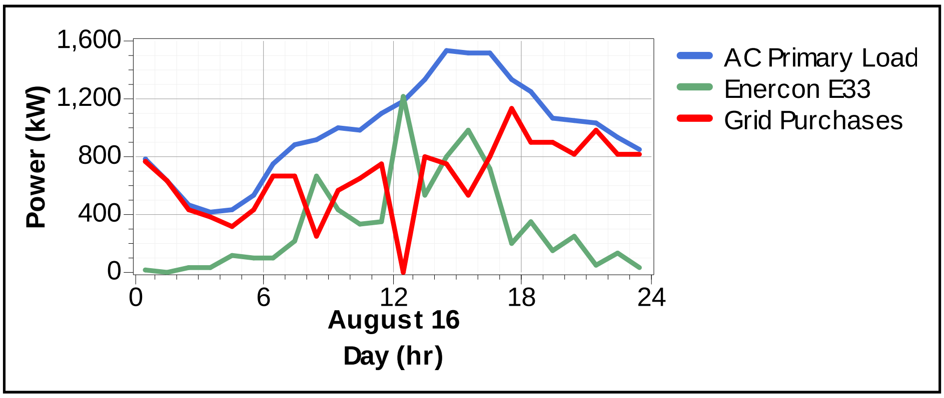

Figure 5-15: Electrical load profile versus wind power & grid purchase by HOMER for Alternative 1-a

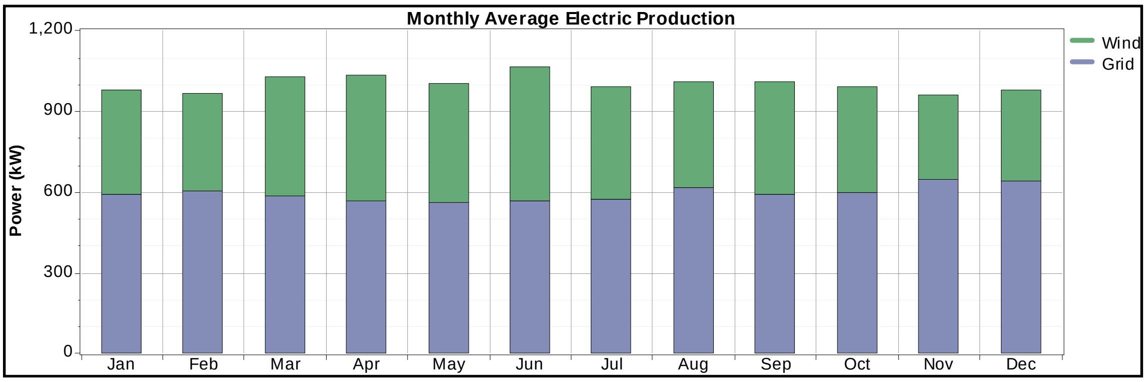

Figure 5-16: Monthly average electric production by Homer for Alternative 1-a

	Wind Power (kWh)	Grid Electricity (kWh)	Fuel (Litre)	LPG (Kg)
Consumption per guest-night	12.36	22.42	2.43 l	0.2
Total annual consumption	2,870,472	5,206,975	564,455	46,457
CO_2 emissions per guest-night (kg)	0	13.23	6.39	0.58
Total annual CO_2 emissions (tonnes)	0	3,072	1,485	136

Table 5-4: Alternative 1-a consumptions and CO_2 emissions

In summary, four different types of energy resources are considered in Alternative 1-a: wind power, grid electricity, diesel fuel & LPG. Table 5-4 shows the consumption rates and CO_2 emissions of the energy production systems in Alternative 1-a based on the same previous assumptions of GtR and occupancy rates.

b. **PV:** in this option, Alternative 1-b, Solar PV cells is used and any shortage in power supply through the PV cells is compensated by the grid. HOMER was used to simulate the daily electricity load profile against the power generated through the PV cells. Several configurations with different capacities were simulated by the software and the optimal configuration is presented in Table 5-5.

System	**Description**	**Electrical Production (kWh/yr)**	**Fraction**
Solar PV	1800 kW 800 kW inverter 800 kW rectifier	3,963,138	42%
Grid purchase	2 x 1 MW transformers	5,467,261	58%
Total		**9,43,399**	**100%**
Primary load (demand)		8,077,447	100%
Excess load		1,062,931	11,3%
Unmet load		0.00	0%

Table 5-5: System configuration and simulation results by HOMER for Alternative 1-b

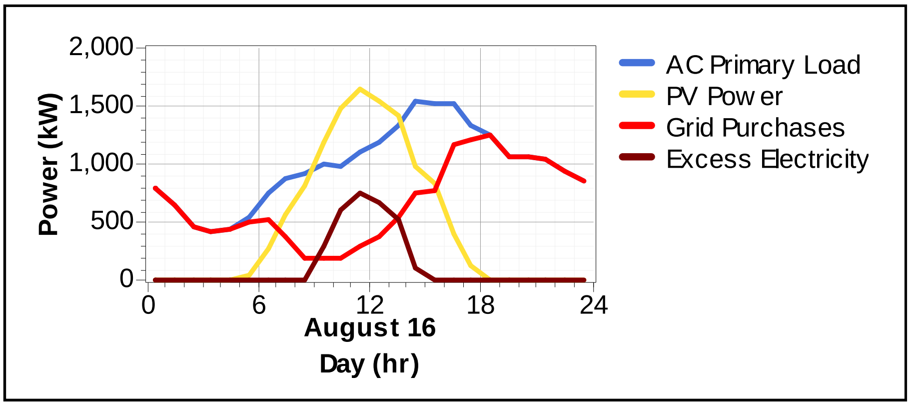

Figure 5-17: Electrical load profile versus solar power & grid purchase by HOMER for Alternative 1-b

Figure 5-17 depicts the electricity load profile for a typical day in August plotted against the power produced by the PV cells and the additional power purchased from the network grid. It is also noted that during the day there is unused power amounting to 11.3% excess power from the annual solar power produced. This can be fed into the grid generating an income to the resort. The monthly average electric production is illustrated in Figure 5-18 showing the proportion of solar energy versus the power supplied by the grid.

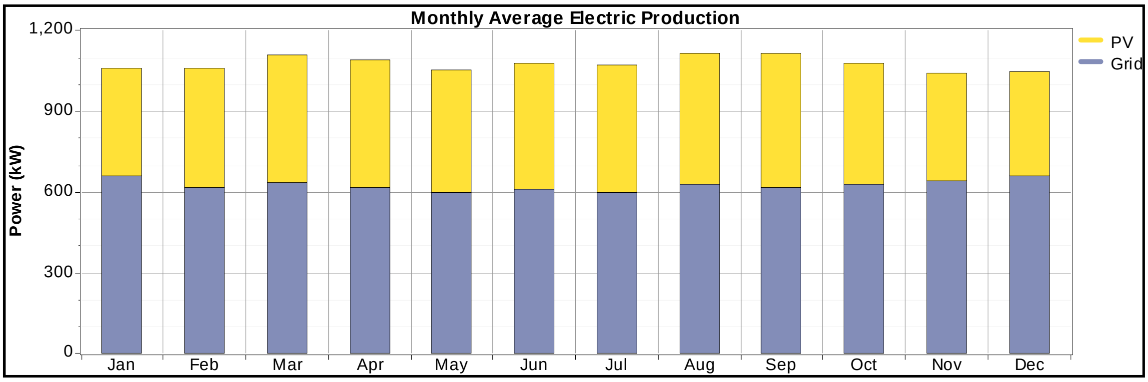

Figure 5-18: Monthly average electric production by Homer for Alternative 1-b

	PV Power (kWh)	Grid Electricity (kWh)	Fuel (Litre)	LPG (Kg)
Consumption per guest-night	11.24	23.54	2.43 l	0.2
Total annual consumption	2,610,186	5,467,261	564,455	46,457
CO_2 emissions per guest-night (kg)	0	13.89	6.39	0.58
Total annual CO_2 emissions (tonnes)	0	3,226	1,485	136

Table 5-6: Alternative 1-b consumptions and CO_2 emissions

Four different types of energy resources are considered in Alternative 1-b: solar power, grid electricity, diesel fuel & LPG. Table 5-6 shows the consumption rates and CO_2 emissions of the energy production systems in Alternative 1-b based on the same previous assumptions of GtR and occupancy rates.

c. **Wind & PV:** in this third option, Alternative 1-c, a combination of WECS and PV cells is investigated. Similar to the previous two alternatives, the grid is used as a backup. HOMER is used to simulate the daily electricity load profile against both wind and solar power. Several configurations with different capacities were simulated by the software and the optimal configuration is presented in Table 5-7.

It is observed that although having two resources of RE, the distribution of available renewable energy did not greatly improve over the days since both solar and wind power happens to have their peak output during the same period on that particular August day (Figure 5-19). In this option, there is unused power amounting to 9 % from the annual renewable power produced. This can be fed into the grid generating an income to the resort. The monthly average electric production illustrated in Figure 5-20 shows the proportion of solar energy versus the power supplied by the grid.

System	Description	Electrical Production (kWh/yr)	Fraction
Wind	6 x 330 kW Enercon E33	2,644,406	30%
Solar PV	500 kW 200 kW inverter 200 kW rectifier	1,100,871	12%
Grid purchase	2 x 1 MW transformers	5,163,347	58%
Total		**8,908,623**	**100%**
Primary load (demand)		8,077,447	100%
Excess load		831,177	9%
Unmet load		0.0131	0%

Table 5-7: System configuration and results by HOMER for Alternative 1-c

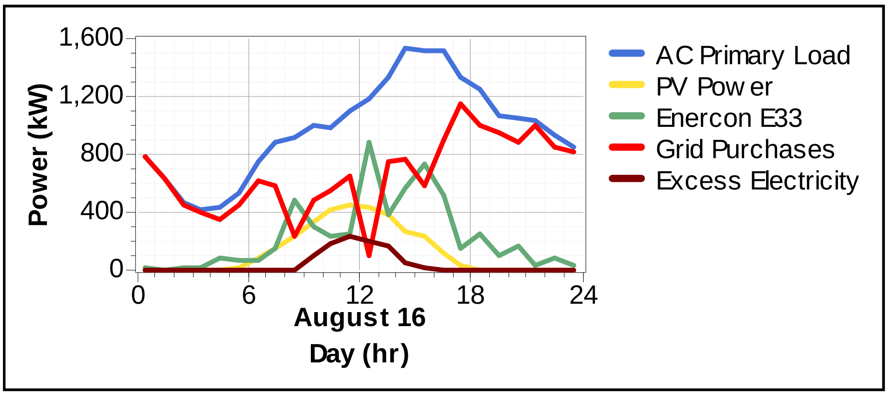

Figure 5-19: Electrical load profile versus solar, wind power and grid purchase by HOMER for Alternative 1-c

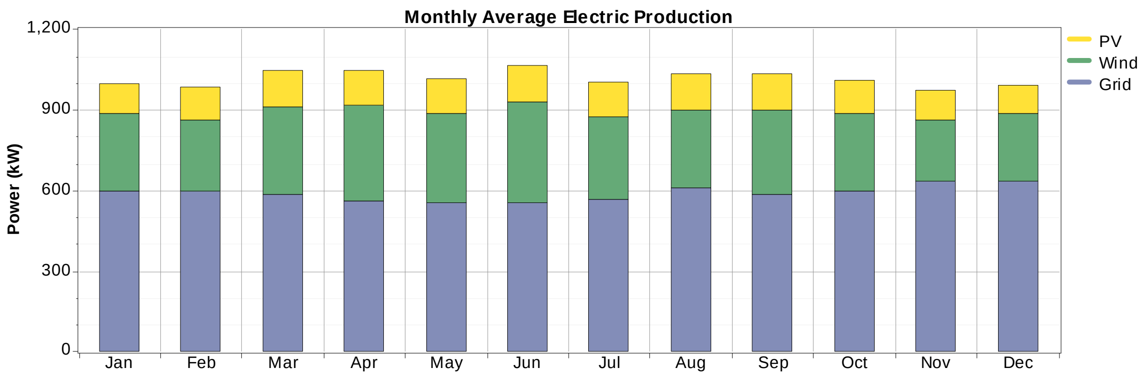

Figure 5-20: Monthly average electric production by Homer for Alternative 1-c

	PV + Wind power (kWh)	Grid Electricity (kWh)	Fuel (Litre)	LPG (Kg)
Consumption per guest-night	12.55	22.23	2.43 l	0.2
Total annual consumption	2,914,100	5,163,347	564,455	46,457
CO_2 emissions per guest-night (kg)	0	13.11	6.39	0.58
Total annual CO_2 emissions (tonnes)	0	3,046	1,485	136

Table 5-8: Alternative 1-c consumptions and CO_2 emissions

Five different types of energy resources are considered in Alternative 1-c: Solar, wind, grid electricity, diesel fuel & LPG. Table 5-8 shows the consumption rates and CO_2 emissions of the energy production systems in Alternative 1-c.

5.4.3 Alternative 2

Alternative 2 follows the same energy production systems for Alternative 1 except for the resource of thermal energy which is modified to integrate solar energy (Figure 5-21).

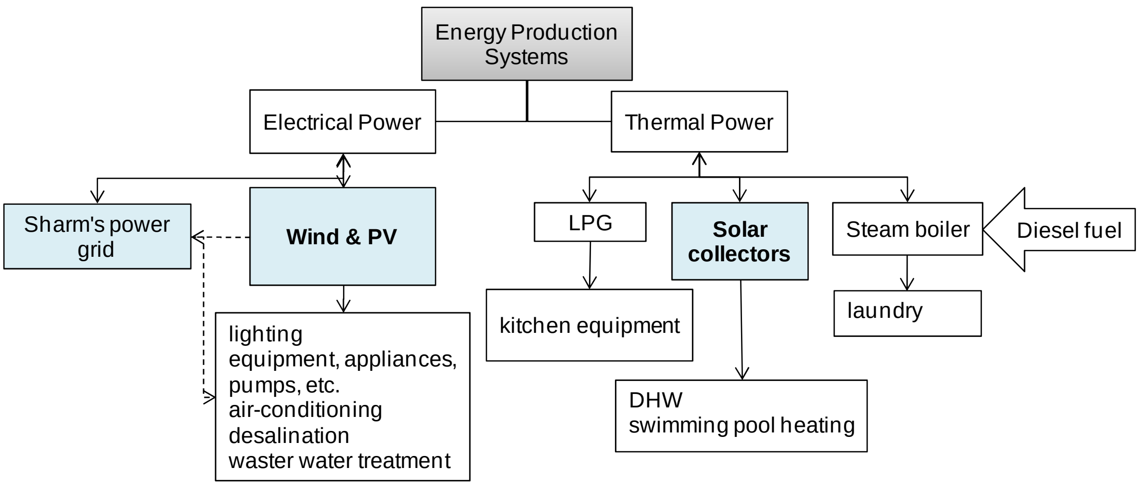

Figure 5-21: Energy production systems for Alternative 2

5.4.3.1 Thermal demand & resources for Alternative 2

It is assumed that by introducing energy efficiency measures, the heating requirements will decrease mainly through the decrease of water consumption as mentioned earlier in section 5.4.1. Solar collectors are used for supplying DHW and swimming pool heating. A smaller steam boiler is used to provide the steam required for operating the laundry equipment.

System	**Description**	**Thermal Production (kWh/yr)**	**Fraction**
Solar collectors for DHW	455 m2 collector, 31,124 l storage	187,400	26%
Solar Collectors for swimming pools	577.30 m2 collector	272,600	
Steam boiler	650 kg/hr (457 kW)	1,314,000	74%
Total		**1,774,000**	**100%**

Table 5-9: System configuration and simulation results for the thermal load by RETScreen for Alternative 2

The RETScreen software is used to assess the thermal energy performance using solar collectors under various operating conditions of the resort. The proposed system configuration for thermal energy and its output is summarised in Table 5-9 and elaborated as follows:

- DHW for main building (130 GR): a central solar collector is simulated using a German product which is available on the local market in Egypt. The system consists of 59 solar panel with a total collector area of 168.74 m^2, 11,549 litre of storage and a heating capacity of 107.79 kW. The annual heating output is calculated 68.9 MWh, representing a renewable fraction of 95%.
- DHW for cluster buildings (214 GR): the solar collectors are simulated using the same German product which is available on the local market in Egypt. The system consists of 100 solar panel with a total collector area of 286 m^2, 19,575 litre of storage and a heating capacity of 182.7 kW. The annual heating output is calculated 118.5 MWh, representing a renewable fraction of 95%.
- Swimming pool, 1200 m^2: the solar collectors are simulated and a system consisting of 230 collectors is proposed. The system has a total area of 577.30 m^2, a heating capacity of 367.1 kW and an annual heating output of 272.6 MWh which represents a renewable fraction of 23%.
- Steam for laundry: the thermal energy required in Alternative 2 is estimated 467 kW versus 550 kW of the B-a-U case. A 15% reduction in laundry needs is assumed as a result of the water efficiency measures taken. The boiler was simulated by RETScreen and the annual thermal output is calculated 1,314 MWh consuming ca. 144,540 litres per year.

Although one can note that the renewable fraction is 26% with respect to the thermal energy, yet the overall thermal energy load profile is still lower compared to B-a-U. This reduction in consumption in addition to using solar energy resulted in a drop in the fuel consumption from 613,200 to 143,228 litres per year.

Electricity is used as backup for supplying DHW in case of deficiency in the energy provided by the solar collectors. However, the electrical consumption will be negligible since the solar energy covers 95% of the total demand. In case of the swimming pool heating, no back up is considered as heating is required only during 4 months of the year.

	PV + Wind power (kWh)	Grid Electricity (kWh)	Solar collector (kWh)	Fuel (Litre)	LPG (Kg)
Consumption per guest-night	12.55	22.23	1.98	2.43 l	0.2
Total annual consumption	2,914,100	5,163,347	460,000	144,540	46,457
CO_2 emissions per guest-night (kg)	0	13.11	0	1,64	0.58
Total annual CO_2 emissions (tonnes)	0	3,046	0	380	136

Table 5-10: Alternative 2 consumptions and CO_2 emissions

Table 5-10 summarises the energy consumptions and CO_2 emissions resulting in Alternative 2. The configuration of Alternative 1-c is chosen as an example to represent the electrical production system in Alternative 2.

5.4.4 Alternative 3

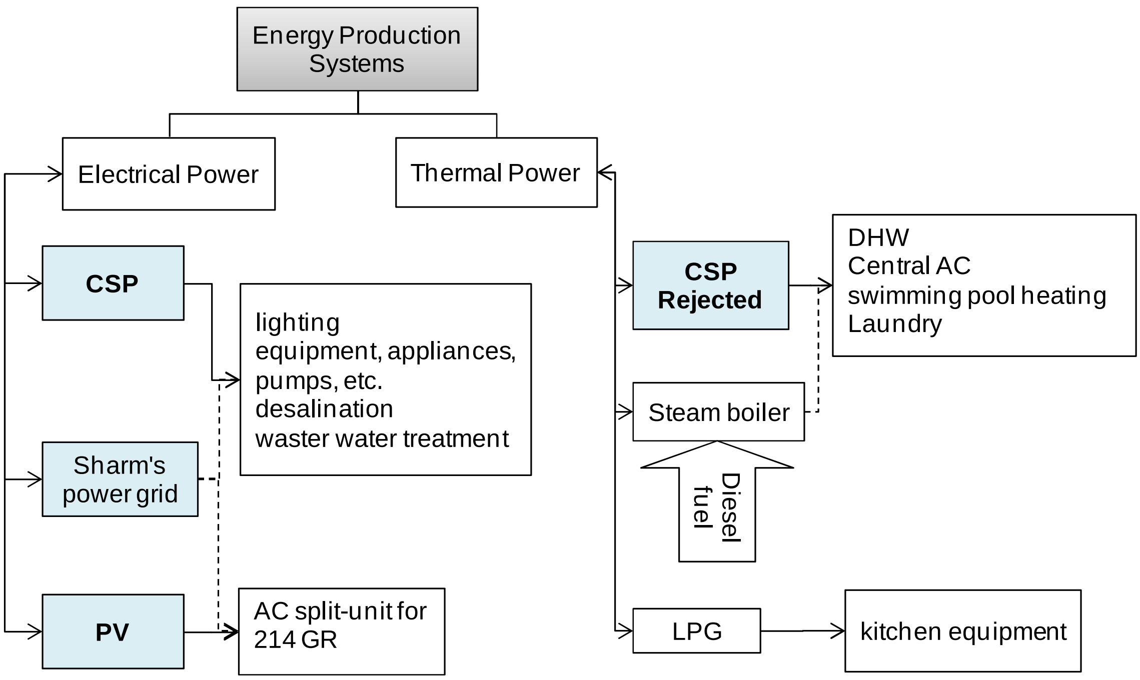

Figure 5-22: Alternative 3 Energy production systems

This alternative combines the production of electrical and thermal energy through the same resource of solar energy. The idea is based on co-generation concept where a CSP system is used to generate electricity while the rejected heat from the system is used to cover the thermal loads. Figure 5-22 demonstrates the energy production systems for Alternative 3. The system consists of two parts: centralised and decentralised. The centralised system covers the main building including public areas and 130 GR as well as restaurants and back of house while the decentralised system covers the 214 GR located in clusters as follows:

- Central air-conditioning for 130 GR and public areas is to be provided through solar energy using the rejected heat from the CSP to operate absorption chillers. On the other hand, PV split units are used to cool the 214 GR located in cluster buildings.
- DWH for the public areas, back of house and the 344 GR of the resort.
- Electricity from the grid is used as a backup to cover shortages and the non-sunshine hours.
- A steam boiler is used as a backup for supplying thermal energy during non-sunshine hours needed for cooling & DHW.

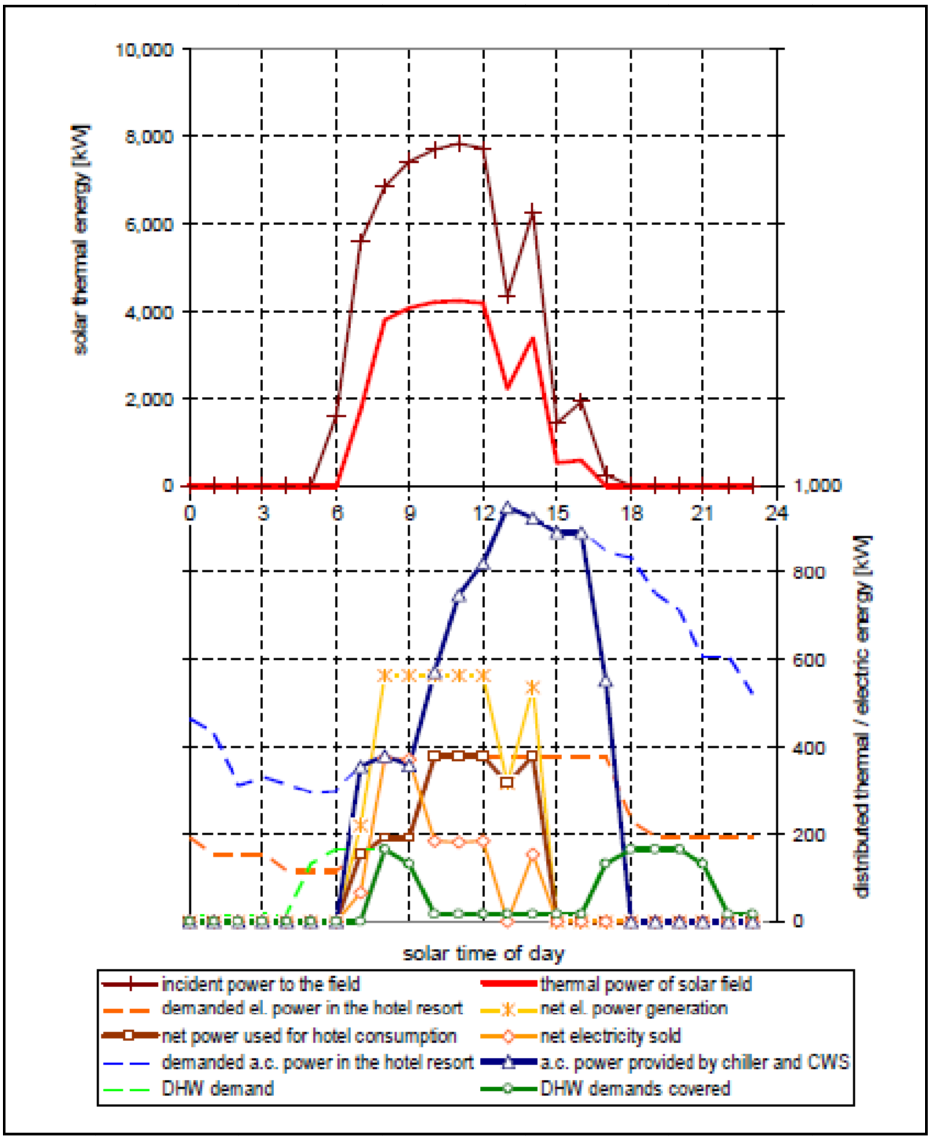

Figure 5-23: Energy produced versus thermal & electrical load profile for a typical day of a tropical resort (Georgei, et al., 2009).

In order to establish a better understanding of the distribution and demand of the energy loads throughout the day with respect to solar energy, the author used, as a guideline, the energy profile of the resort located in tropical area. Figure 5-23 shows the available solar energy from the CSP plant plotted versus the thermal and electrical load of that five stars resort during a typical day (Georgei, et al., 2009). It is noted that most of the cooling load is met by the solar energy since the peak demand for cooling coincides with the timing of incident solar power. Based on that, the author suggests that the energy performance in the resorts of Sharm-El-Sheikh will follow the same behaviour where the solar thermal energy would cover most of the cooling demand and the DHW demand. Regarding the laundry energy requirements, the working shifts are planned during the day time in order to make use of the available solar energy.

5.4.4.1 Electricity demand for Alternative 3

Based on estimations, the author assumes that by introducing solar cooling system in addition to the energy efficiency measures, the peak power demand is 50% of the B-a-U case and ca. 72% of Alternative 1. It is also assumed that the 60% of the energy demand is consumed during the day and 40% during the night. The values of the energy load profile for Alternative 3 are accordingly estimated:

- Peak load of 1.3 MW (centralised CSP) + 0.248 MW (decentralised PV)
- Daily consumption of 15 MWh (central CSP) + 1.5 MWh (decentralised PV). 10.5 MW is consumed during the day and 6 MWh during the night period.
- Average guest-night consumption of 25.92 kWh which is close to the value of the guest-night consumption in Cyprus indicated in Table 3-3.

5.4.4.2 Thermal energy demand for Alternative 3

The thermal energy loads are taken based on the calculations of Alternative 2 in addition to the thermal load required for operating the absorption chillers. It is assumed that as result of reducing the heat gain in the buildings, the cooling demand is lower and the absorption chillers have 80% capacity of those used in the B-a-U case. In the B-a-U case, 4 compression chillers were used with a total cooling capacity of 560 RT while in Alternative 3; the absorption chillers will have a total cooling capacity of 448 RT which is equivalent to 1,575 kW of thermal energy. Assuming a double stage absorption chiller with a coefficient of performance (COP) of 1.2, the total thermal energy demand required to operate the absorption chillers is 1,313 kW. A steam boiler is used as a backup to cover the cooling demand during the night. It is assumed that half the cooling capacity is required during the night with a full load operating period of 4 hours. In summary the thermal load demands are estimated as follows:

- DHW for main building (130 GR): a thermal demand of 107.79 kW, 11,549 litre of storage and an annual thermal demand of 68.9 MWh.
- DHW for cluster buildings (214 GR): a thermal demand of 182,7 kW, 19,575 litre of storage and an annual thermal demand of 118.5 MWh
- Swimming pool, 1200 m^2: a thermal demand of 367.1 kW and an annual thermal demand of 272.6 MWh.
- Steam for laundry: a thermal demand of 467 kW and an annual thermal demand of 1,314 MWh.
- Absorption chillers: a thermal demand of 1,313 kW and an annual thermal demand of 5,749 MWH of which 4,791.2 MWh are consumed during the day and 0.958 MWh during the night hours.

5.4.4.3 Energy resources for Alternative 3

The main energy providers for Alternative 3 are: CSP plant, PV and steam boiler. The following sections present the details about each configuration and its capacity.

5.4.4.3.1 CSP

CSP is still considered novel among RETs and, hence, there are no available software to carry out simulations as in the case of the RETs such as wind, PV, and solar collectors. The author has used basic principles to calculate the output of the CSP in addition to developed experience in similar projects. A static model based on energy flows has been developed through which energy yields can be calculated.

The CSP plant consists mainly of two parts: the solar field and the power block. The following is a list of givens and assumptions considered in the calculations:

- The average direct normal irradiation (DNI) in Sharm el Sheikh is ca. 2900 kW/m^2/annum at an average incident angle of 28° (NASA, 2010). An average of 8 hours of sunshine is considered per day.
- The solar field used in this solution consists of a parabolic trough system produced by Solarlite (Solarlite, 2010). Based on the above DNI value, the system has an output of 0.7 kW/m^2.

The power block consists of the turbine machine and its auxiliary equipment such as condensers, pumps, etc. The efficiency of the turbine is another factor determining the electrical and thermal output from the CSP plant. An efficiency of 20% is taken, i.e., the electrical power produced from the turbine is 20% the thermal energy fed into the turbine. The remaining energy, described as rejected heat, is the amount of thermal energy available in the form of steam. Based on the above assumptions, the size of the CSP plant is estimated as follows:

- Turbine electrical output = 1300 kWe
- Turbine thermal input = 1300 / 20% = 6550 kWth
- Turbine rejected heat = 6550 – 1300 = 5240 kWth
- Solar field output = 6550 kWth
- Solar collector area = 6550 / 0.7 = 9,357 m^2
- Footprint of solar field = 28,000 m^2
- Annual electrical output of the solar field = 3,976 MWh
- Annual usable thermal energy = 15,300 MWh

The thermal energy amounting to 5,240 kWth rejected by the turbine system is used to operate the absorption chillers, laundry equipment and supply of DHW and swimming pool heating. A cold water storage and a hot water storage are provided to extend the supply of cooling and DHW through the first few hours of the night before resorting to using the backup system.

In case of the electricity supplied by the CSP and exceeding the resort’s demand, there is the option of feeding the excessive power into the grid or selling it to neighbouring resorts. Vice versa, during the periods of non-sunshine hours and the demand exceeding the supply from the CSP, the grid is used to cover these shortages.

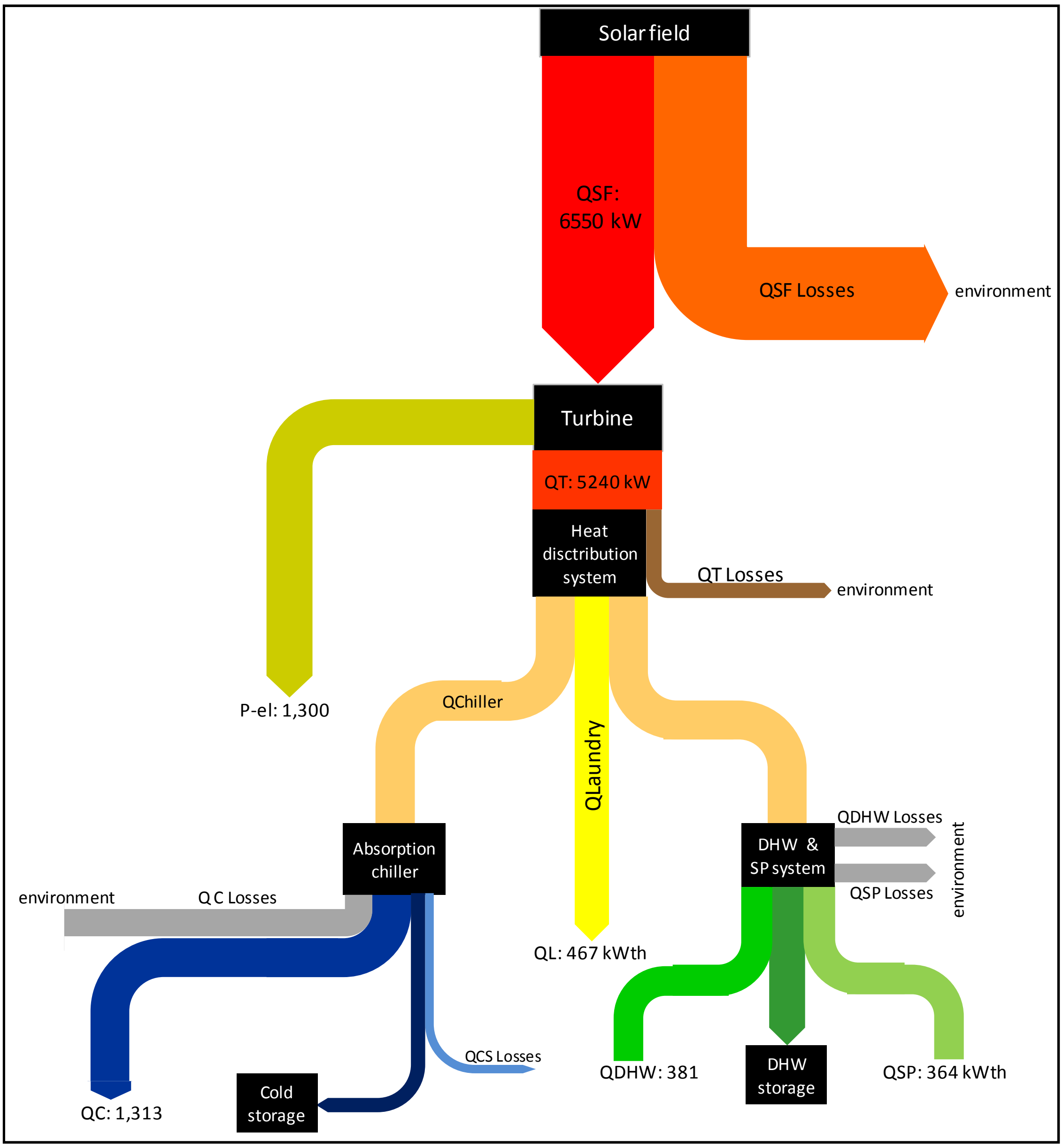

Figure 5-24: Sankey diagram of the CSP energy use in Alternative 3

The Sankey diagram in Figure 5-24 illustrates the energy flow of the proposed CSP system where the energy flows are represented as arrows. A typical example is chosen where the turbine is working under nominal conditions. In order to produce 1,300 kW of electricity, P-el with a net electric efficiency of 20 %, the turbine requires an input of 6,550 kW, QSF, of thermal power from the solar field. In a conventional steam turbine process, the difference of 5,240 kW, QT, is rejected into the environment by a cooling system. In this case, the heat leaving the turbine system is used for DHW, steam production and to operate the absorption chillers. A fraction of the thermal energy, QT Loss, entering the turbine can neither be recuperated nor converted into electricity (radiation losses, internal electricity consumption and friction in bearings). The remaining thermal energy is still available for the absorption chiller, laundry and DHW. The part QChiller is used to operate the chiller providing chilled water for air-conditioning. A major part of the chilled water is used directly in providing a cooling of 1,313 kW, Qc. The share of cooling not used because of low air conditioning demand is stored in cold water storage system.

The rest of the thermal energy which is not used for the chiller is used for the DHW system and the laundry steam needs. The DHW systems uses a part directly as per the actual demands and another part are stored in the hot water storage.

5.4.4.3.2 PV split air-conditioning units

The air-conditioning system for the 214 GR in clusters consists of split units which operate using PV power. The energy demand for those units is as follows:

- Peak load 248.4 kW
- Average daily consumption during sunshine hours 1.5 MWh

PV cells with a capacity of 250 kW is used to operate the split units during 6 hours of sunshine while during non-sunshine hours, the power required is covered by the grid.

5.4.4.3.3 Steam boiler

As previously mentioned above, the CSP system will mainly operate the absorption chillers during the day in addition to a cold water storage which can extend the solar cooling into a few hours during the night. However, a backup is required and accordingly, a steam boiler with a thermal capacity of 703 kW is used. It is assumed that the boiler will operate 4 full load hours. The average annual thermal output of the boiler is estimated to be 985.227 MWh having an equivalent fuel consumption of 105,405 litre.

Table 5-11 summarises the previously selected energy resources, their output and the overall energy demand for Alternative 3. It can be noted that the renewable fraction of the electrical system is 67% of the complete supply system where the remaining 33% are supplied through the grid. The power produced through the CSP system exceeds the demand during the day at non-peak hours and can be fed into the grid. On the other hand, the thermal system has a renewable fraction of 94%. The non-renewable part is only 6% which is only needed to operate the absorption chillers during the night hours. It can be noted that the thermal supply is much higher than the thermal demand as a result of large amount of rejected heat from the CSP system. This excess heat can be used to heat additional swimming pools or in other processes; for instance, it could be used for solar desalination once the technology is mature and feasible for a resort application.

Table 5-12 gives an overview of the energy consumption and CO_2 emissions resulting in the case of Alternative 3.

System	Description	Electrical Production (kWh/yr)	Fraction
Electrical system:			
CSP Power (centralised)	Collector area of 9,357 m2	3,976,000	59%
Solar PV (decentralised)	250 kW	547,500	8%
Grid purchase	1 MW transformer	2,190,000	33%
Total		6,713,500	100%
Primary load (demand)		6,022,500	90%
Excess load		691,000	10%
Unmet load		0.0	0%
Thermal system:			
CSP thermal energy (centralised)	Collector area of 9,357 m2	15,300,800	94%
Steam boiler	703 kW capacity	985,227	6%
Total		**16,286,027**	**100%**
Primary load (demand)		7,253,363	46%
Excess load		8,762,664	54%
Unmet load		0.0	0%

Table 5-11: System configuration for Alternative 3

	CSP + PV Power (kWh)	Grid Electricity (kWh)	CSP thermal (kWh)	Fuel (Litre)	LPG (Kg)
Consumption per guest-night	14.14	9.43	26,98	0.47	0.2
Total annual consumption	3,832,000	2,190,000	6,268,136	108,375	46,457
CO_2 emissions per guest-night (kg)	0	5.56	0	1,23	0.58
Total annual CO_2 emissions (tonnes)	0	1,292	0	285	136

Table 5-12: Alternative 3 consumptions and CO_2 emissions

5.4.5 Summary of Design alternatives

Item	**B-a-U case**	**Alternative 1-c**	**Alternative 2**	**Alternative 3**
Electricity resource	Grid	WECS, PV, Grid	WECS, PV, Grid	CSP, PV, Grid
Annual RET electricity produced, MWh / %	0	3.745 / 42%	3.745 / 42%	4,524 / 67%
Annual non-RET produced electricity, MWh	11,173 / 100%	5,163 / 58%	5,163 / 58%	2,190 / 33%
Annual electricity demand, MWh	11,173	8,077	8,077	6,023
Annual excess electricity, MWh / %	0	831 / 9%	831 / 9%	691 / 10%
Thermal energy resource	Oil steam boiler	Oil steam boiler	Solar collector, Oil steam boiler	CSP, Oil steam boiler
Annual RET produced thermal energy, MWh / %	0	0	460 / 26%	15,301 / 94%
Annual non-RET produced thermal energy, MWh / %	62 / 100%	62 / 100%	1,314 / 74%	985 / 6%
Annual thermal demand, MWh	62	62	1,774	7,253
Total calorific value of non RE consumption, MJ/GN	263.45	215.46	148.21	110.81

Table 5-13: Summary of design alternatives

In the previous sections five solar alternatives were developed, of which 3 were chosen for further evaluation along with the B-a-U case. Table 5-13 provides a summary of all the design alternatives offering an overview of the different energy productions systems and their outputs. The average non-RET electricity and fuel consumed by guest-night are converted into calorific value in megajoul (MJ) and are added together to give an indication of the energy performance of each alternative. Alternative 3 has the maximum renewable fraction and the least energy consumption among the 4 design alternatives with a value of 110 MJ per GN.

6 Analysis and Evaluation Methodology

This chapter establishes the method used for analysing and evaluating the design alternatives developed in the previous chapter. A holistic approach is essential in evaluating the design alternatives which embraces economic and environmental implications over the whole life cycle of the resort. It is often that the life cycle cost receives no or at least minimum attention within the investment decision for a project. For the investor, the initial capital cost is of the utmost interest when deciding between different design alternatives. This might go back to the existing economic situation, where the investor is seeking to complete the construction of his project in the shortest period of time possible and start generating the return on investment as soon as possible; hence, reaching a positive financial result. It is also often the case that environmental impacts are overseen or neglected. This explains why the interests of the investor and, especially, that of the construction or developer company concentrates neither on a life-cycle orientated view nor on a holistic approach, but focuses instead on the minimisation of capital costs.

The chapter starts with an overview of the economic indicators used in investment decisions, followed by an outline of the life cycle costing (LCC) method and the extent of its use (see Figure 6-1). Based on both investment calculation and LCC methods, the author will develop an environmental life cycle cost (ELCC) model for the evaluation of resort projects. The objective of the ELCC model is to achieve a comprehensive evaluation of each alternative encompassing not only economic aspects but as well the environmental impact over the project life cycle.

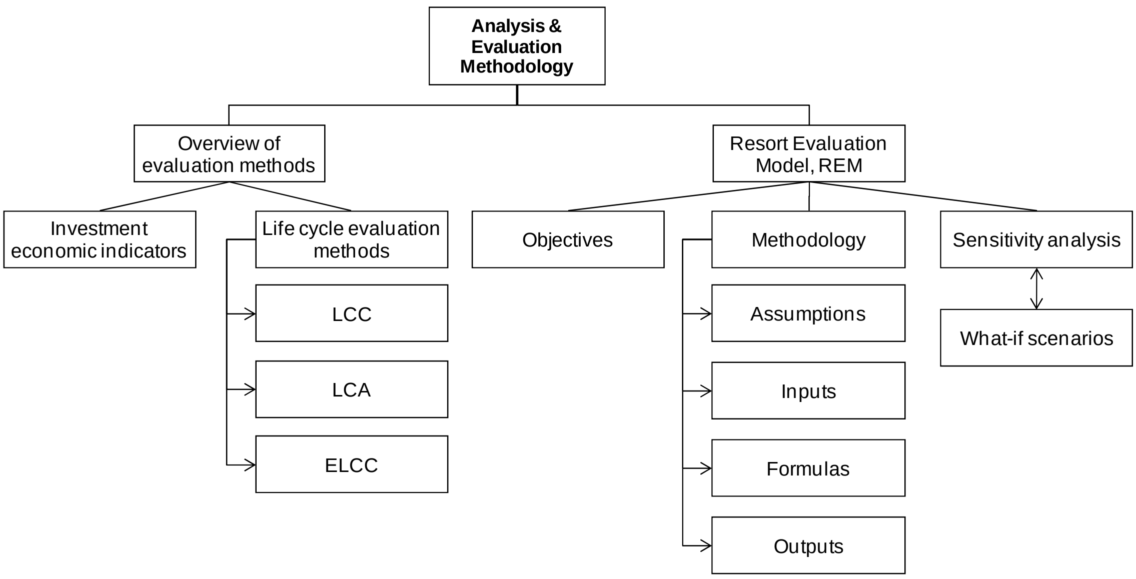

Figure 6-1: Outline of chapter 6

6.1 Overview of evaluation methods

The investor usually seeks to know what the present value of the future investment is, or how long it will take to generate returns and it is often the case that his decisions are based on the expected return on investment. If the investment is unprofitable in the long run, then it is seen unwise to invest in it unless the project is for social reasons only. Typical investment decisions in the building industry include the decision to adopt new technologies or to follow conventional methods. It may also be wished to evaluate whether to spend more on a new technology with the benefit of future cost savings during operation of the project. There are several economic indicators that are well known and often used in making such investment decisions.

6.1.1 Investment economic indicators

Two of the most common economic indicators are the net present value (NPV) and internal rate of return (IRR), where both are closely related since both are time-adjusted measures of profitability and their mathematical formulas share a common basis. Both NPV & IRR would lead to the same decision with respect to an individual project. As shown in Figure 6-2, if the cash flow is discounted at k_1, the NPV is positive and the IRR > k_1, then the project can be accepted while at a discount rate of k_2, a negative NPV and IRR < k_2, then the project would be rejected.

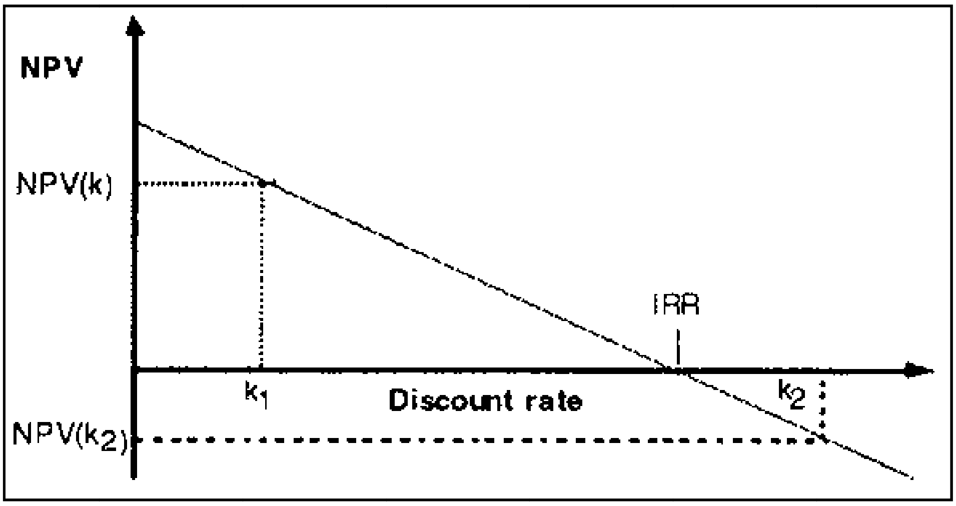

Figure 6-2: Net present value versus internal rate of return

The NPV takes into account that the value of money decreases with time, based on the first basic principle of finance, the time value of money: A Euro today is worth more than a Euro tomorrow (K. Herzog & Henseleit, 2004). For example, assume one person, A, has Euro 1,000 on hand, another person, B, has Euro 1,000 promised 10 years from now, and a third person, C, is collecting Euro 100 per year for 10 years. Each of them has an asset of Euro 1,000; however, these assets might not be equivalent in terms of today's purchasing power since these assets are spread across different points of time. Therefore, a baseline time reference must first be established in order to determine whose assets are worth more. The NPV method is then used to bring back all monies to the chosen baseline. Assuming an interest rate of 7%, and a baseline time reference as today, the calculated NPV of each of those three persons are valued at: Euro 1000, 508 and 702 respectively. Person A has, accordingly, the most worth asset valued at today.

The IRR is the discount rate at which the NPV of a project equals zero. This rate means that the present value of the cash inflows for the project would equal the present value of its outflows.

A third economic indicator the profitability index (PI) is used for ranking projects where it is the ratio between the present value of future cash flow and the initial investment. An PI of 1 indicates breakeven; any value lower than one would indicate that the project's present worth is less than the initial investment and vice versa. As the value of the profitability index increases, so does the financial attractiveness of the proposed project.

Many investors like to know the payback period (PP) which is defined as the time it takes the cash inflows from a capital investment project to equal the cash outflows and is usually expressed in years (CIMA).

Considering the special type of building project investigated in this thesis, the question is raised which economic indicators are most suitable for evaluating a resort type project. It is worth noting that we are not considering the whole investment of the resort and, hence, the main revenue stream generated by the resort through selling or renting rooms is not part of this evaluation. The objective here is not to decide whether to invest in a resort business or another type of business operation, rather to decide on the most suitable design alternative. Accordingly, economic indicators such as IRR, PI and PP cannot be calculated for an individual case, since not all costs and revenues are considered. This leaves us with one method, the NPV, which allows us to compare alternatives. The cash-out and cash-in flows discounted to the present time are added together yielding a negative NPV since cash out dominates the total cash flow. The lower the absolute value of the NPV, the more attractive the project is. NPV is the method used in calculating the LCC of a project.

The IRR, PI and PP could be, however, used when comparing two alternatives where an additional investment is required in one of them that would yield cost savings and/or benefits versus the other.

6.1.2 Life cycle evaluation methods

Cost and value are not always well managed by clients. Some clients focus on the wrong goal – lowest capital price rather than best value; but concentrating on the initial capital cost of a project does not always give value for money, especially when all the incurred costs, savings, environmental and social values throughout the life time of a project are overlooked.

In this section, the different types of life cycle evaluation are outlined. Understanding the differences between each methodology is necessary before defining the objectives of the cost model to be used in evaluation.

6.1.2.1 Life cycle costing

LCC is a common tool that is used in evaluating the economic efficiency of a project and investment options while considering the impact of all incurred costs during the project life which allows a consistent comparison of alternatives whilst considering all relevant cost parameters from cradle to grave. LCC of an asset is, hence, considered as the present value of the total cost of that asset over its operating life, including initial capital cost, occupation costs, and the cost or benefit of the eventual disposal of the asset at the end of its life (RICS). Examples of such costs and benefits are:

- Acquisition costs and/or revenues.
- Procurement costs such as initial construction costs, purchase or lease of equipment, interest, fees and other costs related to project implementation.

- Recurring costs such as rent, operation rates, maintenance, repair, replacement and/or renewal, energy, utilities and other costs related to the operational phase of the asset.
- Revenues such as resale of recycled materials, sale of generated power, rental income and other.
- Disposal costs and/ or revenues such as demolition costs, dismantling costs, and resale of used equipment.

When the life time of all alternatives is equal, then the lowest LCC represents the best alternative for the economic aspect. For example, a lighting system is expected to cost €10,000 to install today; energy and lamp replacement are estimated to be €750 & €500 annually respectively. A one-time replacement is anticipated to cost €3,000 at the tenth year; and the system is expected to have a salvage value of €2,000 after its life cycle of 20 years. Table 6-1 shows the LCC of the investigated lighting system which is calculated to be €21,501 over a life time of 20 years and at a 10% discounting rate. This value can be compared with the LCC of another lighting system calculated on the same basis.

Payment	**Value**	**number of payments**		**NPV**
		single	**annual**	
Initial Cost	€10,000	0		€10,000
Energy Cost	€750		20	€6,385
Maintenance Cost	€500		20	€4,257
Replacement Cost	€3,000	10		€1,157
Salvage Value	€ (2,000)	20		€-297
Present Worth of the flow of costs				€ 21,501

Table 6-1: LCC of a lighting system (Kirk & Dell'isola, 1995)

<table>
<tr><th>Standard</th><th colspan="7">Phases of LCC</th></tr>
<tr><td>ISO 15686-5 (2004)</td><td colspan="3">Acquisition</td><td>Use & Maintenance</td><td colspan="2">Renewal & Adaption</td><td>Disposal</td></tr>
<tr><td>GEFMA 100-1 (2004)</td><td>Conception</td><td>Design</td><td>Construction</td><td>Operation & Utilisation</td><td>Renovation</td><td>Unoccupied</td><td>Recycling</td></tr>
<tr><td>Ö NORMA A 7000 (2000)</td><td>Project idea</td><td>Project development</td><td>Construction</td><td colspan="3">Utilisation</td><td>Demolition/Disposal</td></tr>
</table>

Table 6-2: Phases of LCC according to various standards, adapted from (Kati Herzog, 2005)

LCC is also expressed through other terms which bear the same meaning such as: Whole Life Costing and Through Life Cost. For the purpose of consistency, the author has chosen to use the term LCC throughout the thesis. Although LCC is recognized by several standards, different terminologies might be used with respect to the project life phase as indicated in Table 6-2. The shaded area highlighted in the table represents the optimal phase where the evaluation of options and alternatives should take place. During the acquisition/conception/project idea phase there is ample opportunity to introduce changes with minimum costs of rework.

The ISO standard 15686 on service life planning defines LCC as: “A tool to assist in assessing the cost per performance of construction work, aimed at facilitating choices where there are alternative means of achieving the client’s objectives and where those alternatives differ, not only in their initial costs but also in their subsequent operational cost” (Edwards, Bartlett, & Dickie, 2000).

6.1.2.2 Life cycle assessment

Life cycle assessment (LCA) is a tool used for measuring and evaluating the environmental burdens associated with a product system or activity by describing and assessing the energy and materials used and released to the environmental over the life cycle. It is used to achieve sustainable building practices by considering its environmental impacts. Proper design and material selection are critical to minimize those in-use environmental loads (Kotji, Schuurmans, & Edwards, 2003). The similar term life-cycle analysis is sometimes used to describe the same process.

LCA compiles the inputs and outputs of product and evaluates the current or potential environmental aspects and impacts such as resource consumption and environmental releases throughout the product’s life cycle – from raw material acquisition through production, use, end-of-life treatment, recycling and final disposal, i.e., *cradle to grave*. LCA is often used in:

- identifying opportunities to improve the environmental performance of products at various points in their life cycle;
- assisting decision-makers in industry, government or non-governmental organizations in setting their strategic plans, objectives prioritising, redesign of product or process;
- selecting relevant indicators of environmental performance, including measurement techniques; and
- identifying opportunities for resources efficiencies.

LCC and LCA are used interchangeably in the construction industry. Both methods deal with components used and their service life, maintenance and operational implications and disposal at end of their life time. However, LCA is more concerned with environmental impacts while LCC is more concerned with financial impacts discounted to present value over time. The key differences between LCC and LCA are (Kotji, et al., 2003):

- Conventional LCC methods do not consider the process of making a product; they are concerned with the market cost, whereas LCA considers production.
- In LCC costs are usually discounted over time, whereas environmental impacts are not discounted.

6.1.3 Environmental life cycle costing

A third type of life cycle evaluation was introduced in 2007 by Hunkeler, Lichtenvort, & Rebitzer (2008) known as ELCC which summarizes all costs associated with the life cycle of the project relating to real money flows in addition to externalities that include environmental implications. The objective of combining environmental and economic performance of a project is to identify win-win situations and to be able to optimize trade-offs between the environmental view and the economic/business view.

Figure 6-3 depicts the framework of LCC versus ELCC of a project. Internal costs are directly connected to the investment cost which concern all costs and revenues within the project life cycle. Meanwhile, externalities are external costs such as environmental subsidies; taxes; and penalties.

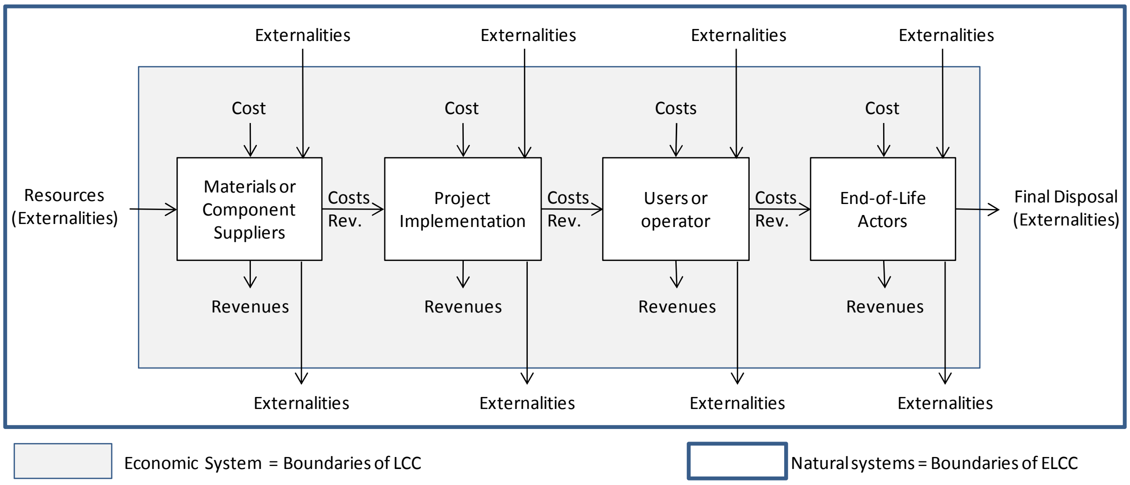

Figure 6-3: Conceptual framework of ELCC, adapted from (Hunkeler, et al., 2008)

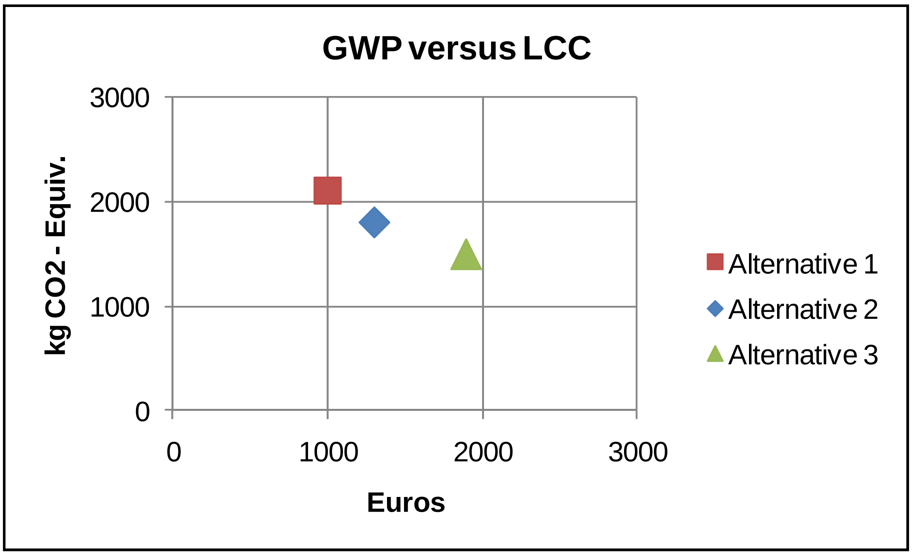

Figure 6-4: ELCC portfolio presentation of 3 alternatives (Hunkeler, et al., 2008)

Although the scope of ELCC differs from LCA since it is concerned with both costs and environmental impacts, however, there are overlaps and connections between both methods where the quantities of flows calculated from LCA can be used to calculate costs in the ELCC. For example, amounts of energy consumption can be used to calculate operation costs during the use of the project.

The results of ELCC can be presented in the form of a table or in the form of a portfolio presentation where the overall LCC in monetarily terms is plotted against the global warming potential (GWP) in kgCO_2 equivalent (Figure 6-4).

6.2 Resort evaluation model

Due to the individuality and type of the case study with respect to general buildings, the author developed a Resort Evaluation Model (REM) based on the ELCC method where the resort performance in terms of life cycle cost and environmental impact, expressed as equivalent CO_2 emissions, are captured and evaluated (Figure 6-5).

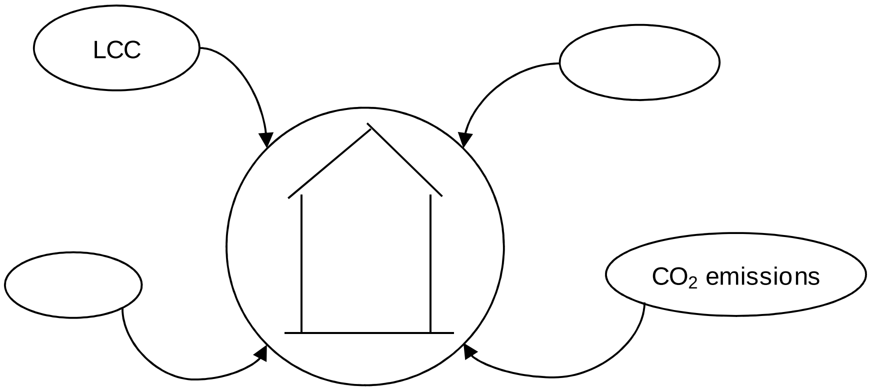

Figure 6-5: The performance of a resort evaluated in REM, adapted from performance of buildings (Kotji, et al., 2003)

6.2.1 Objectives of the REM

Most environmental impacts of energy consumption take place in the atmosphere such as: Acid pollution, ozone depletion and green house gases emission. For the purpose of this research, the atmospheric emissions CO_2 is chosen to represent the GWP as the only environmental impact in the REM due to its worldwide impact while the other atmospheric pollutant emissions such as dust, NOx and SO_2 result from power plants and have a regional impact.

The scope of evaluation in the REM is limited to the energy use in a resort and the corresponding CO_2 emissions during the operation phase of the project. It is also to be noted that REM is valid for resorts with GR capacity ranging from 200 to 800 and with a minimum occupancy of 70%. The energy audit carried out in chapter 4 shows that the GN consumption differs greatly with occupancies less the 70%. Also, the energy audit did not examine resorts with GR numbers below 200 or above 800 and, hence, GN consumption values for resorts outside this range have to be analysed in terms of their consumption pattern before using the developed REM. Additionally, the following parameters are not considered in the REM analysis:

- The production phase of the materials and products used in the construction of the resort.
- The transport of materials to the resort site as well as equipment and personnel.

- The construction waste during the construction phase.
- The energy consumption during the construction phase.
- Demolition of the establishment.

The REM is aimed to be used in both prospective and retrospective evaluation for future and existing resorts. Compared to other models, REM enables the evaluation of the synergy effect of different technologies and energy efficiency measurements. For example, the HOMER tool evaluates the LCC of micro-power plants focusing on power production only while REM evaluates the ELCC of combined power and thermal production systems. The output of REM is expressed in a functional unit in addition to the total value of the project in order to be able to benchmark it with respect to other resorts.

6.2.2 REM methodology

To demonstrate the concept of the REM evaluation tool within the scope of this thesis, the author developed a simplified version of REM using a group of interlinked Excel worksheets based on the LCC formulas, methodology and assumption explained in the next sections of this chapter. The worksheets are divided into 3 categories: Input sheets, calculation sheet and output sheets. The inputs and outputs are expressed per function units which in this case are: GN for annual costs and CO_2 emissions, and GR for capital and life cycle costs. The flow chart in Figure 6-6 outlines the REM process where it starts with compiling the data required for the inputs of the model. Two types of data are required: Technical data such as occupancy, supplied energy and energy consumption rates; and economical parameters such as capital investment costs, energy tariffs, financing parameters, revenues and benefits. The ELCC is then calculated using the LCC formulas and the results are presented in terms of LCC per GR and equivelant CO_2 emissions per GN. Sensitivity analysis is performed on different parameters to identify the critical parameters and the extent of their impact on the decision making. The end results are presented to decision makers and could be compared to benchmark values if available or other design alternatives. In case of unfavourable results, further alternatives could be developed and revaluated, or the evaluated alternative can be rejected or postponed to future implementation when certain parameters are expected to change such as change in laws, regulations and or prices.

The developed REM spreadsheet was validated using other evaluation tools such as HOMER & RETScreen calculating the LCC or NPV of individual technologies. For example, the LCC of a PV station was calculated by both REM and HOMER to confirm the proper functionality of REM; similarly, RETScreen was used to validate the ELCC results of evaluating each of CSP and solar collector technologies by REM. Generally, no major discrepancy is expected since all models are based on the same formulas.

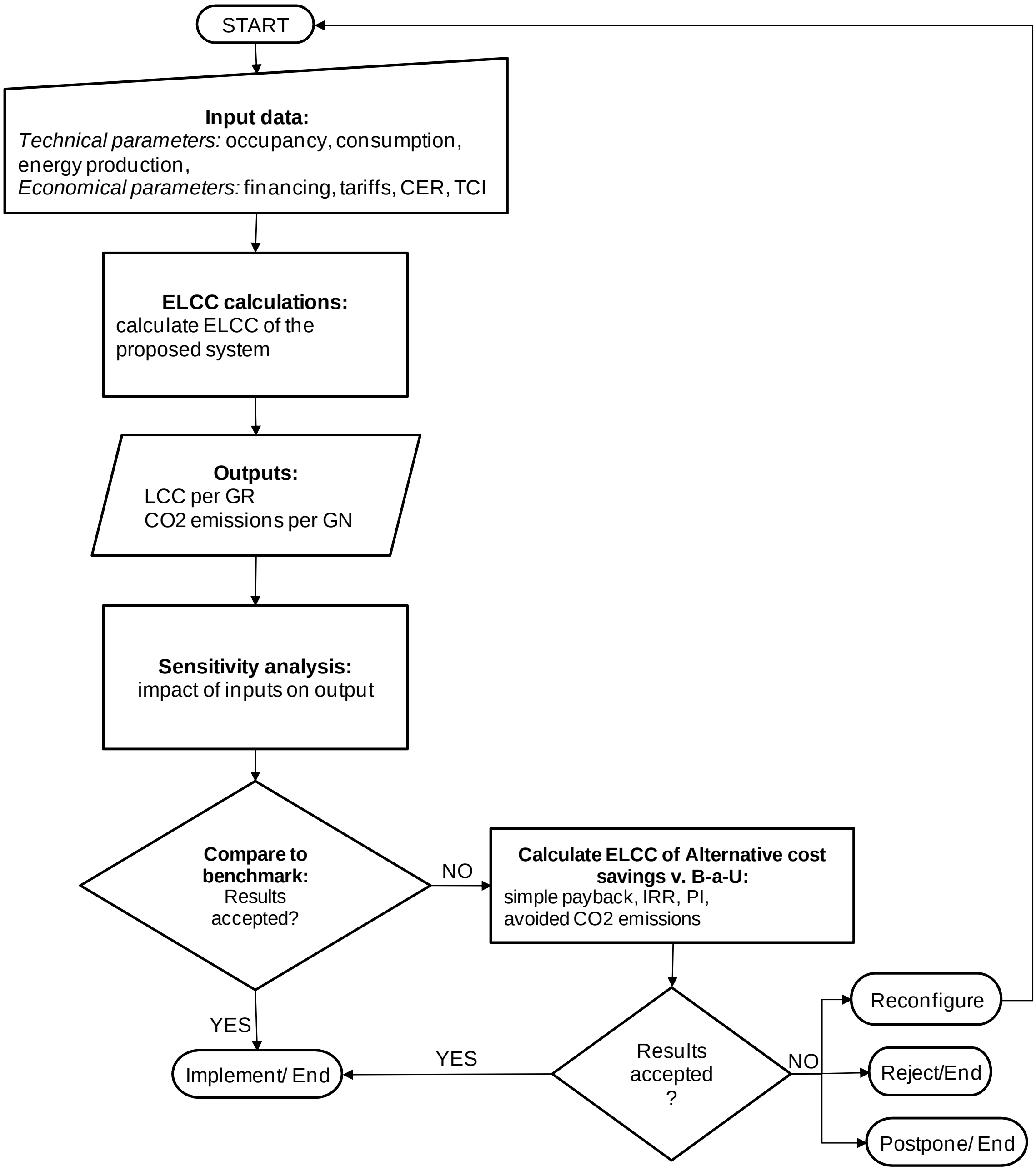

Figure 6-6: REM analysis process

6.2.2.1 REM assumptions

Several variables constitute the REM calculations whether they are entered directly as input parameters or they formulate part of the LCC formulas. Those direct variables can be input and changed as required while those indirect variables are fixed in the REM. Before proceeding further with the REM, it is essential to establish a common understanding of those variables. The following is a list of assumptions concerning the variables included in the developed REM:

- Project life is the life of the whole resort establishment and which is typically determined by the client according to economic factors based on value and depreciation as well as how long the client is expected to hold an interest in that asset. RICS state that buildings usually end their life before the actual end of their physical life. Forty years would be considered as a long building life while 20 years or less would be considered a relatively short building life. It has been widely recommended by Kirk & Dell'isola (1995) to adopt an analysis period of 25 to 40 years. Yet, it should be noted that, no matter how the analysis period is selected, costs that are to be incurred far in the future, say beyond 25 years, become inconsequential both in size and their effect on the LCC analysis. The project life time is a direct input on the economical input sheet of the REM which has been designed to allow a maximum life time of 35 years. In the analysis of the case study in the next chapter, 25 years is chosen as an input value due to the individuality of a resort as an establishment type which is often subject to complete refurbishment before completing 25 years. Also, in cases where energy prices or feed-in tariff play a major role in evaluating the LCC, there would be high uncertainty since it would be difficult to predict the prices of energy or feed-in tariff for periods exceeding 25 years. The existing feed-in tariff laws worldwide are valid for 10 to 25 years depending on the country.

- Service life is the life of a product or a building element. It is determined either technically based on physical durability and reliability of properties, or obsolescence based on factors other than time or use patterns. In the REM analysis**,** the service life of the main elements is not a direct input parameter and is integrated within the maintenance and replacement (M&R) costs.
- M&R costs are distributed equally over the project life time and are expressed as a percentage of the total capital investment (TCI). The M&R cost is a direct input in the REM model and a value of **2%** is assumed for the case study.
- Salvage value is the value of the elements when they no longer have a use or are in function. This is might be determined by the client or market projection. It is a direct input and is entered as a percentage of the TCI; a value of **5%** is assumed in the case study.
- Discount rates may be possibly determined by other investment opportunities open to the client. In the REM, the discounting rate is an indirect variable and is calculated using the weighted average capital cost (WACC) formula mentioned under section 06.2.2.3. in the REM, WACC can be varied resulting in different discount rates. In the case study, several scenarios will be simulated to examine its effect on the REM outputs.
- Inflation rate is the rate of increase of the average price level over a given period of time. It can also be defined as the rate of decrease in the purchasing power of money over the same given period of time. Real figures do not consider inflation while nominal figures do. To determine the NPV in an LCC calculation, it does not matter if real or nominal figures are used as long as the approach is consistent; either nominal figures, namely all cash flows and discount rates, or real figures for all parameters are being used. For both scenarios the total NPV will be the same (K. Herzog & Henseleit, 2004). This approach is also supported by Kirk & Dell'Isola (1995) where they state that "as long as the LCCA is used for the comparison of alternatives, the use of the after-inflation discount rate and constant dollars produces the same result as any other reasonable method of analysis". In REM the inflation is, accordingly, neglected and only real values are considered.
- Cost growth is the increase or decrease in the price of an individual item with or without a corresponding increase or decrease in value versus to inflation which is a general increase in the prices of goods and services over time in the economy as a whole, without a corresponding increase in values. Although inflation can be neglected when comparing alternatives, yet cost growth cannot be neglected in some cases. For example, growth of the cost of labour will probably not affect the LCC, however, the growth of energy cost will have the most effect on the least energy-efficient alternative and it's LCC. The difference be-

tween the cost growth and inflation is known as differential escalation. Since the objective of REM is to compare alternatives, current prices should be adjusted incorporating the differential escalation for items that have a cost growth exceeding the general inflation rate. Accordingly, REM incorporates the escalation rate and is applied to M&R costs as well as operation costs which are highly affected by any price fluctuation in the energy prices. This parameter is a direct input variable and in the case study, it is simulated with different values in order to establish its impact on the REM results.

- Taxes; regardless whether taxes are considered or not, it is important to obtain consistency. As it would be very time consuming, intransparent and cumbersome to estimate LCC on an after tax basis, it is more feasible to assess LCC on a pre-tax basis. Therefore, the entire approach of LCC of constructions of buildings is to be considered before taxes (K. Herzog & Henseleit, 2004). Based on that, REM does not consider any taxes in its calculations.
- To reduce the time and complexity of the analysis, those project elements that will be the same in any of the alternatives under consideration are to be identified and removed or fixed during the comparative analysis (Kirk & Dell'isola, 1995). Therefore, the author has removed all common items from the REM calculations and only items related to the energy performance of the resort are considered and which vary in terms of cost, capacity and/or performance from one alternative to the other.

6.2.2.2 REM input data

The first step in any LCC analysis is to list all costs according to different phases of life. Table 6-3 is an example of a detailed checklist of different cost elements that can be included in an LCC for a construction project.

Capital Cost	
Land	
Fees on acquisition	
Design team professional fees	
Demolition and site clearance	
Construction price of building work	
Cost of statutory consents	
Taxes	
Furnishings	
Other capital costs	
Commissioning expenses	
Decanting charges	
Financing Costs	
Finance for land purchase and during construction	
Finance during period of intended occupation	
Loan charges (public sector)	
Operating Costs	
Energy	
Cleaning	
Rates	
Insurances	
Security and health	
Staff	

Management and administration of the building	
Land charges	
Energy conservation measures	
Internal planting	
Equipment associated with occupier's occupation	
Water	
Gas	
Fuel	
Maintenance, replacement and alteration costs	
Main structure	
External decorations	
Internal decorations	
Finishes, fixtures and fittings	
Plumbing and sanitary services	
Heat source	
Space heating and air treatment	
Ventilating systems	
Electrical installations	
Gas installations	
Lift and conveyor installation	
Communications installation	
Special and protective installations	
External works	
Gardening	
Residual Values	
Resale value	
Demolition costs	

Table 6-3: Checklist of costs and values of an asset (RICS)

Not all of the above cost items are taken as input in the REM since the objective is to compare alternatives with respect to the energy performance of a resort rather than the whole project items. Several of the above mentioned items are common and do not change from one alternative to the other and will accordingly not affect the result of the decision, (Kirk & Dell'isola, 1995). The main cost items chosen to be used as input for the REM are as follows:

- TCI cost elements such as:
    - Building envelope elements, for example, insulated or non-insulated walls, type of glazing, etc.
    - Sanitary works based on centralized or decentralized system which will have an impact on the size of the sewage network.
    - Electrical installations whether they are transformers, EMS, type of lighting & lamps, power saving devices, etc...
    - Electrical energy resource which could be an RET installation, grid based or a fuel based generator.
    - HVAC whether centralized or decentralized air-conditioning, electrically or thermally operated system, etc.
    - Thermal energy resource such as boiler, solar collectors, heat recovery system, etc.

    - Desalination Station which could vary in type or capacity from one alternative to the other
    - Waste water treatment station which again could vary in type or capacity.
- Financing costs covering any loans and/or grants
- Operation cost which is the total annual cost of consuming grid electricity, fuel, LPG, and any other fossil fuel used for supplying energy to the resort.
- M &R cost which is the total annual costs for maintenance and any part or equipment replacement.
- Revenues generated through either sale of any surplus energy to a third party or through a feed-in tariff agreement.
- Benefits that could be generated through trading of certified emission reductions (CERs) or tax reductions.

In the REM worksheets, the above mentioned costs are entered in terms of the following input data as indicated in Table 6-4:

Economical Input Data	**Technical Input Data**
Equity, %	Average annual occupancy, %
Fund grant, %	Guest to room ratio
Cost of finance, %	Average GN electricity demand, kWh
Expected return on equity, %	Average GN thermal energy demand, kWh
Feed-in tariff, €/kWh	Annual RET produced electricity, kWh
CER price, €/tCO_2	Annual non-RET produced electricity, kWh
CER trading term, years	Annual RET produced thermal, kWh
Cost escalation factor, %	Annual non-RET produced thermal, kWh
Total capital investment, €	
Project life time, years	
M&R cost, % of TCI	
Electricity purchase price, €/kWh	
Fuel purchase price, €/litre	
Salvage cost, % of TCI	

Table 6-4: REM Input parameters

6.2.2.3 REM formulas

The second step in the REM is to convert all the above resulting costs, which spread over the project life time, using the NPV method to the present value in order to make them comparable over the project life time. The formula used in the REM calculations is based on the LCC formula used in the building construction (K. Herzog & Graubner, 2002), (K. Herzog & Henseleit, 2004) as follows:

$$LCC(t=0) = H + \sum_{t=0}^{t_{max}} \frac{N}{(1+d)^t} + \frac{A}{(1+d)^t}$$

Where,

d = discount rate for adjusting cash flow to present value

H = Total capital Investment

N = costs of operation, maintenance repair and replacement

A = salvage costs

t = number of life time years

Additionally, the following formula was integrated in the REM calculation worksheet:

- PWA, present worth of an annuity/recurring costs including differential escalation (Kirk & Dell'isola, 1995), where e is the growth escalation rate

$$PWA = N \times \frac{v(v^t - 1)}{v - 1}, \text{ where } v = \frac{1+e}{1+d}$$

- WACC which determines the discount rate, where E & D are the equity and debt value in an investment respectively. R_e & R_d are the cost of equity and debt respectively (Investopedia, 2010),

$$WACC = \frac{E}{E+D} \times R_e + \frac{D}{E+D} \times R_d$$

Comparing the LCC might not be conclusive in decision making. In alternatives where savings and/or revenues are generated over the life time of the project, it might be required to determine PP; PI and IRR by considering the incremental capital cost versus the annual savings between two alternatives. Accordingly, the formulas for calculating IRR, PI and PP were added to the REM.

6.2.2.4 REM outputs

The main results of the REM are presented in the following format:

- The LCC, €/GR; the calculated life cycle cost per guest room before debt and after debt. Both cases are considered to observe the effect of the cost of finance and/or grants.
- The emissions, kgCO_2 /GN; the equivalent CO_2 emissions produced by a guest-night.
- The Annual avoided equiv. CO_2 emissions; the annual savings of CO_2 emissions when compared to a B-a-U case. This value is useful when considering issuing CER under the CDM programme.
- The IRR, PI and payback in case of evaluating incremental costs and savings between two alternatives.

6.2.3 Sensitivity analysis

It is of the essence to assess the effect of uncertainty or risks on the results of any LCC. Sensitivity analysis is recommended since the input data for LCC are based on estimates, variables and/or assumptions rather than known quantities and fixed prices and rates. The sensitivity analysis determines how the value of one parameter is affected by variation in the value of a second parameter on which it depends. These are often called the output and input parameters, respectively (Kirk & Dell'isola, 1995). This method is, accordingly, applied to the REM process in order to determine how the sensitive the REM outputs are.

The breakeven point, defined as the value of the cost element that causes the LCC of the lower-cost alternative to equal the LCC of the higher-cost alternative, are also determined using the sensitivity analysis results.

The author has used What-if Analysis Manager software, an add-in tool for Microsoft Excel, (JABSOFT, 2005) in performing the sensitivity analysis in the REM spreadsheets. The outputs of the sensitivity analysis are presented in tables and charts.

6.2.4 What-if-scenarios

The sensitivity analysis examined the influence of individual parameters in the REM identifying the most critical once. Based on which and with respect to the case study, several What-if scenarios are established and simulated reflecting possible changes in the energy structure in Egypt that might occur in the future considering the new developments in the electricity law underway. Different scenarios of financial structure are also investigated to determine its impact on the LCC. The following what-if scenarios are defined:

- What-if the cost of finance increased to 8% instead of 5.5%? Under the current economic conditions, there is always the possibility that debt interest rates could increase.
- What-if there was no debt, i.e., equity of 100% instead of 30%? Although 30%/70% equity/debt is a typical ratio, however, some owners choose to completely finance their project, depending on the size of the project and its scope.
- What-if the differential escalation rate is 5% instead of 2%? This is the case when the government decides to gradually relieve the subsidies over a defined period of time or an increase in global energy prices is foreseen.
- What-if the electricity and fuel prices where 0.13 €/kWh and 0.5 €/l instead of 0.035 €/kWh and 0.11 €/l respectively? This scenario shows the impact of energy prices and subsidies on decision making and selection of technologies.
- What-if the CER price is ±50% of the assumed price? Should the project join the CDM programme, what would be the financial impact there be changes in the estimated trading value of the CER.

In addition to the above What-if scenarios, three further settings are considered as follows:

- Setting 1 is the current status in Egypt where no RE feed-in tariff framework for small to medium entities is provided and, hence, any RET electricity generated by a small enterprise or individual cannot be fed into the network grid. This setting is named ‘no feed-in’.

- Setting 2 is the same as Setting 1, provided that the project could join the CDM programme and trade the issued CER resulting from CO_2 savings. This setting is named 'CER + no feed-in'.
- Setting 3 assumes that Egypt did in fact introduce a feed-in tariff law and any small to medium entity can feed its RET generated electricity into the gird at an advantageous tariff in accordance with its policy for promoting RE and environment sustainability.

Having developed the basis for evaluating the ELCC of resorts, the developed REM tool is applied in the next chapter to the case study different alternatives with the objective of determining the status of applying solar resort concept in Sharm el Sheikh specifically and in Egypt generally.

7 Resort Evaluation Modelling of Case Study

In this chapter the REM analysis method, developed in chapter 6, is applied on the different design alternatives developed in chapter 5. The objective is to evaluate and compare the economic and environmental performances of the different alternatives including the B-a-U case. A sensitivity analysis will determine which parameters have a major influence on the outputs and could play an important role in decision making.

First, the B-a-U case is analysed establishing a base line for comparison. This is followed by the analysis of the 3 solar design alternatives: 1, 2 & 3. For each alternative, input parameters are first defined in line with the LCC elements outlined in chapter 6, followed by the REM simulation and the sensitivity analysis. The inputs and outputs are presented in a tabular form. At the end of the chapter, the results are discussed and explained. Figure 7-1 shows an overview of this chapter's contents.

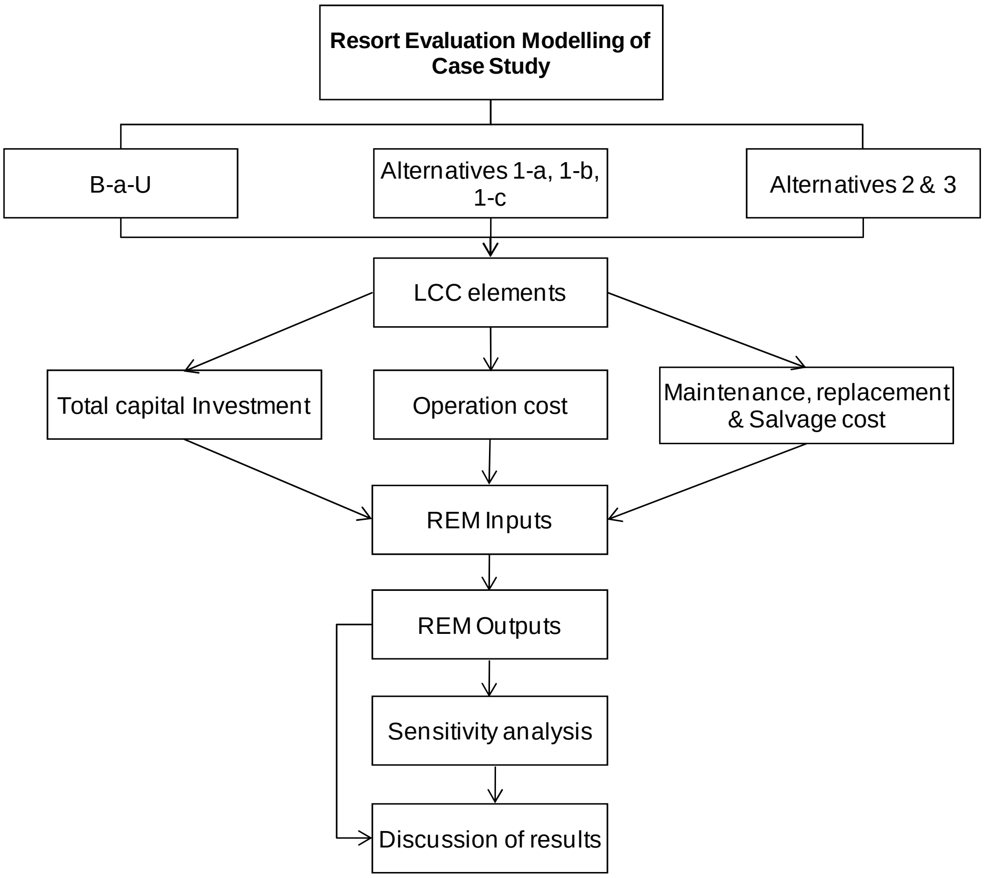

Figure 7-1: Outline of chapter 7

7.1 REM for Business-as-Usual case

This is the B-a-U case representing the most common practices at current resort installations in Sharm el Sheikh which depend mostly on using fossil fuels as an energy resource: Electric network grid and diesel fuel.

As explained in chapter 6, the prices and elements that are common in all alternatives are not taken into consideration in the REM analysis as the objective is comparing the ELCC of both alternatives and evaluating the overall investment of the whole resort. The following is a list of the items considered in the REM analysis in the B-a-U case:

- **Building works including walls and glazing:** Single red brick walls are considered as well as single glazing. No thermal wall insulation is used.
- **Sewage network:** The sewage network extends all over the resort as a result of having a centralized waste water treatment system.
- **Electrical installations:** The main element considered in the TCI is the transformers with a total capacity of 2.7 MW.
- **Central air conditioning:** Air cooled central air conditioning system is used for cooling and ventilating the public areas and 130 guest rooms.
- **Split unit air conditioning:** Split air conditioning units are used to cool the remaining 214 guest rooms.
- **Steam boilers:** fuel operated steam boilers are used to provide the resort facilities with DHW and steam.
- **Landscape lighting:** Normal electrical lighting system was used for illuminating the large landscape.
- **Seawater desalination plant:** An RO system is installed to supply the resort with 500 m^3/day of fresh water.
- **Waste water treatment plant:** A mechanical system with a capacity of 400 m3/day is used to treat the waste water producing a recyclable quality of water that can be used for irrigation purposes.

7.1.1 Total capital investment for B-a-U

Pos	Item	Cost (Euro)
1	Building works	364,081
2	Sanitary & Fire Fighting Works	144,677
3	Electrical Works	50,000
4	Air Conditioning	1,438,094
5	Steam boilers	293,779
6	Landscape	66,667
7	Desalination Station	745,968
8	Waste Water Treatment Station	282,258
	Total Capital Investment, TCI	**3,385,524**
	TCI per GR	**9,482**

Table 7-1: Total capital investment costs of the B-a-U case

The capital investment costs used in the B-a-U case are based on actual market data and the project costs of Resort 6 under appraisal. The author was the appointed project manager of that project from 2001 until 2004 and, hence, had access to the actual project costs. The current construction market prices have increased by 50% over the last 10 years due to inflation and increase in commodities price. Accordingly, the project actual prices from the years 2001/2004 have been factored by 50% to be compatible to today's market prices. In all alternatives, the costs are expressed in Euros and are based on an exchange rate of 1 Euro to 7.50 EGP.

The TCI for the above mentioned items considered in the ELCC amounts to Euro 3,385,524 which is equivalent to Euro 9,482/GR. A summary of the cost breakdown is indicated in Table 7-1

7.1.2 Operation costs for B-a-U

Consumption and tariff rates are two main parameters that define the operation costs. Consumption is mainly dependent on the total number of guests in the resort, i.e. occupancy and guest to room ratio. Tariff rates are mainly dependant on the market price for commodities as well as government subsidies. Until date, the tariff rates in Egypt, including Sharm el Sheikh, do not fluctuate much since they are set and subsidized by the government. The energy prices used in calculating the operation costs of the case study are taken 0.035 €/kWh and 0.11 €/litre for electricity and diesel respectively, reflecting the growth in prices over the last 3 years and the latest energy bills of 2010. Using the rates of consumption estimated in section 5.2.3 the operation costs are calculated and presented in Table 7-2 based on the following formulas:

Operation cost per GN = energy unit price x GN consumption

Total annual consumption = GN consumption x occupancy% x GtR x 365 days

Total annual operation cost = total annual consumption x energy unit price

Resource	Unit Price (Euro)	Consumption /GN	Operation cost / GN	Total Annual Consumption	Total Annual Operation Cost (Euro)
Electricity	0.035	48.1 kWh	1.68	11,172,957	391,053
Fuel	0.11	2.43 l	0.27	564,455	62,090

Table 7-2: B-a-U consumption and Tariff rates

The values calculated in Tables 7-2 are based on 100% occupancy and a GtR of 1.85. In the REM analysis, only two parameters are considered in calculating the operational costs: electricity and diesel fuel. LPG is neglected as it remains constant in all design alternatives as illustrated in chapter 5 in addition to playing a minor role in the overall energy consumption of the resort.

7.1.3 Maintenance, replacement & salvage costs for B-a-U

During the survey of the resorts in Sharm El-Sheikh and the interviews carried out with the responsible chief engineers, the author was not able to gather detailed and accurate information about the costs of M&R and how often it occurs during the life time of the project. However, it was mostly recommended to consider a value of 1 to 2% of the TCI as an annual estimation for the M&R costs. Although repair and replacement do not occur regularly or at equal intervals, however, for the purpose of this research, their cumulative costs are distributed evenly along the project life time and added to the annual maintenance cost. A total value for M&R of 2% is chosen for this case study. Similarly, salvage costs were difficult to determine since most of the interviewed resorts do not exceed 10 years old. An assumption that the salvage costs are 5% of the TCI is made and occurring once, at the end of the life cycle of the project.

7.1.4 REM Inputs for B-a-U

Figure 7-2 & Figure 7-3 illustrate the REM input excel worksheets for the technical and economical data respectively. The cells highlighted in blue allow the user to enter the specific data of each project and vary in the values of those direct parameters while the other non-highlighted cells contain built-in formulas. The technical input parameters for the B-a-U case based on the explanation outlined in chapter 6 are as follows:

- Average annual occupancy = 100%
- Average GtR ratio = 1.85
- Average electricity consumption = 48.1 kWh/GN
- Average fuel consumption = 2.43 l/GN
- Average annual amount of produced electricity by RET = 0 kWh
- Average annual amount of produced thermal energy by RET = 0 kWh

While the economical input parameters are:

- Equity to debt ratio = 30% : 70%
- Cost of finance = 5.5%
- Expected return on equity = 15%
- Term of loan = 10 years
- Cost escalation factor = 2%
- Total capital investment = Euro 3,385,524
- Project life time = 25 years
- O&M cost as percentage of TCI = 2%
- Electricity purchase price = 0,035 Euro/kWh
- Fuel purchase price = 0,11 Euro/l
- Salvage cost as percentage of TCI = 5%

TECHNICAL INPUT SHEET		blue boxes with yellow text are for Data Input text in blue are calculated	
Project Name:		Scenario:	
Resort Design		Business-as-Usual Case	
Location:		Number of Guest Rooms:	
Sharm El Sheikh		344	

	Energy Consumption			Energy Production	
C1	Average Annual Occupancy	100%	ER1	Annual Amount of produced electricity by RET, kWh	-
C2	Average no. of occupied rooms per year	125.560	ER2	Average produced RET electricity, kWh / GN	-
C3	Guest to Room Ratio	1,85	ER3	Annual Amount of produced electricity by non-RET, kWh	11.172.957
C4	Average no. Of guest-nights, GN, per year	232.286	ER4	Average produced non-RET electricity, kWh / GN	48,10
C5	Average Electricity consumption / GN, kWh	48,10	ER5	Annual Amount of produced thermal energy by RET, kWh	
C6	Annual Electricity consumption, kWh	11.172.957	ER6	Average produced RET thermal energy, kWh / GN	-
C7	Average Fuel consumption / GN, l	2,43	ER7	Annual Amount of produced thermal energy by non-RET, kWh	5.131.409
C8	Annual Fuel consumption, l	564.455	ER8	Average produced non-RET thermal energy, kWh / GN	22,09
C9	Average Thermal Energy consumption / GN, kWh	22,09		CO2 Emissions	
C10	Annual Thermal Energy consumption, kWh	5.131.409	CE1	CO2 conversion factor 1 MWh Grid Electricity : 1 ton Co2	0,59
	Energy Demand		CE2	CO2 conversion factor 1 litre Diesel fuel : 1 ton Co2	2,63
DD1	Surplus in supply, kWh / year	-	CE3	Annual amount of equivalent CO2 emissions	8.077
			CE4	Average amount of equivalent kg CO2 / GN	34,77

Figure 7-2: REM technical input sheet for B-a-U case

ECONOMICAL INPUT SHEET		blue boxes with yellow text are for Data Input text in blue are calculated	
Project Name:		Scenario:	
Resort Design		Business-as-Usual Case	
Location:		Number of Guest Rooms:	
Sharm El Sheikh		344	

Financial Parameters			Project Parameters		
FP1	Equity ratio, ER	30%	PP1	Total Capital Investment, TCI	3.385.524,00 €
FP2	Fund Grant	0%	PP2	Project Life time in years	25
FP3	Debt ratio, DR	70%		ANNUAL COSTS:	
FP4	Cost of finance, Rd	5,50%	PP3	M & R Cost as % of TCI	2,0%
FP5	Expected return on equity, Re	15,00%	PP4	Annual M&R Cost, AMRC	67.710 €
FP6	Term of loan in years, ToL	10	PP5	Electricity purchase price per kWh	0,035 €
FP7	Term of Grant in years, ToG	0	PP6	Fuel purchase price per litre	0,11 €
FP8	Equity by Owner, E	1.015.657 €	PP7	Annual Electricity Operational Costs	391.053 €
FP9	Grant amount	- €	PP8	Annual Fuel Operational Cost	62.090 €
FP10	Debt to Bank, D	2.369.867 €		ANNUAL REVENUES & BENEFIT	
FP11	Weighted Average Cost of Capital, WACC	8,35%	PP9	Annual Revenue from selling electricity fixed	- €
FP12	Feed-in Tariff fixed rate per kWh	0,035 €	PP10	Annual Revenue from selling electricity add-on	- €
FP13	Feed-in Tariff added premium per kWh	- €	PP11	Annual Revenue from CER	- €
FP14	Feed-in Tariff added premium term in years	0		Salvage Cost	
FP15	CER price per ton CO2	- €	PP12	Salvage Cost as % of TCI	5,0%
FP16	CER term in years	0	PP13	Total salvage Cost, TSC	169.276 €
FP17	Cost Escalation factor	2,0%			
FP18	Change in feed-in Tariff	0,0%			
FP19	Change in CER prices	0,0%			

Figure 7-3: REM economical input sheet for B-a-U case

7.1.5 REM Outputs for B-a-U

Using the input values mentioned in the previous section 7.2.5 and the assumptions and methodology outlined in chapter 6, two sets of outputs are produced by the REM: Before and after debt as follows (see Figure 7-4):

- Before debt; the total LCC of the resort is Euro 9,752,879 and Euro 28,351 per guest room.
- After debt; the total LCC for the resort is Euro 9,478,300 and Euro 27,553 per guest room.
- The amount of equiv. CO_2 emissions is 35 $kgCO_2$ per guest-night amounting to 8,077 tCO_2 /annum.

It can be noted that the difference between the LCC before and after debt is not significant and, hence, the LCC after debt per guest room will be used henceforth as a base for comparison. Having a negative NPV and no generated benefits nor cost savings, the IRR and payback periods are not calculated.

REM OUTPUT SHEET

Project Name:	**Scenario:**
Resort Design	Business-as-Usual Case
Location:	**Number of Guest Rooms:**
Sharm El Sheikh	344

Economical parameters

Before Debt & Grant	per GR	Total	Including Debt & Grant	per GR	Total
LCC before Debt	28.351 €	9.752.879 €	LCC after D & G	27.553 €	9.478.300 €
NPV of Cash Flow before Debt	- 28.351 €	- 9.752.879 €	NPV of Cash Flow After D & G	- 27.553 €	- 9.478.300 €

Environmental parameters

	kg per GN	tonnes/Annual
Average equivelant CO2 emissions	34,77	8.076,56

Figure 7-4: REM output for the B-a-U case

7.1.6 Sensitivity analysis for B-a-U case

A sensitivity analysis was carried out on the financial parameters of the project to identify their impact on the LCC value. Firstly, the equity ratio and cost of finance are varied having a direct impact on the WACC which is the discount value used in calculating the LCC and NPV:

- Equity ratio varying from 30% to 100%.
- Cost of finance, Rd, varying from 5% to 8%.

The variation in those two parameters has accordingly resulted in changing the value of the WACC from 8% to 15% which consequently resulted in a variation of the LCC from 28,110 to 20,893 €/GR. It is common sense that with a 100% equity share in the project and no debt, the LCC reduces significantly by 26%. Meanwhile, maintaining the original equity ratio of 30% and increasing the cost of finance to 8% resulted in a smaller reduction of ca. 10% in the LCC. The detailed results of the sensitivity analysis are presented in a table attached in the appendices.

Using the original input values, a second sensitivity analysis was carried out on the LCC value by varying cost escalation factor from 2% to 8%. The idea was to reflect the global annual increase in energy prices which might eventually result in annual increase in the energy prices in Egypt even though still subsidised. For example, the current electricity price is 0.035

€/kWh and it was assumed that there will be an annual increase of 2% in the operation costs and energy prices. The question is what might be the change in the LCC value if the Egyptian government decides to apply a higher annual increase to the current subsidised energy prices. Figure 7-5 shows the resulting variation in the LCC value from 27,553 to 42,592 €/GR. For instance, a cost escalation factor of 5% will lead to an increase in the LCC by ca. 22% reaching 33,562 €/GR.

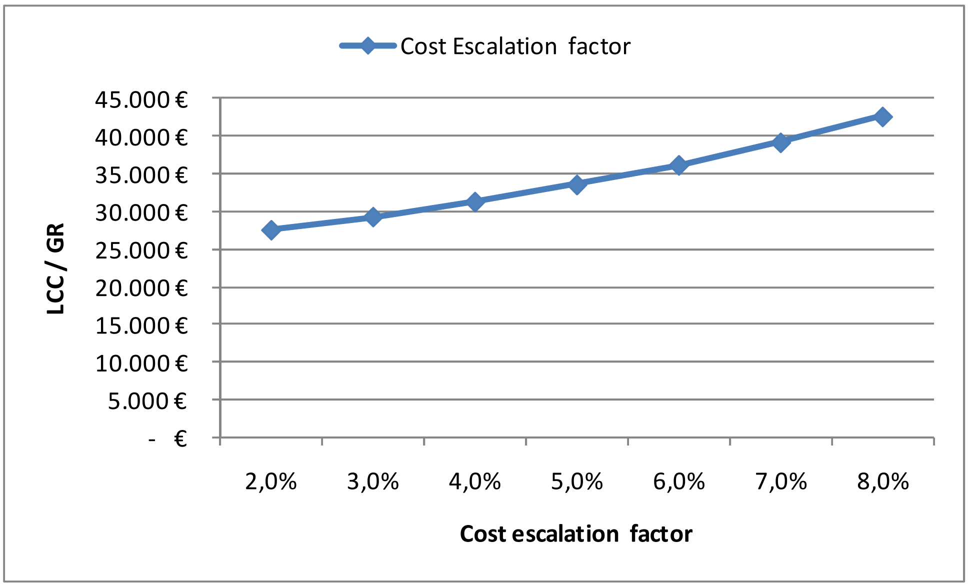

Figure 7-5: Variation in LCC value versus cost escalation factor for B-a-U case

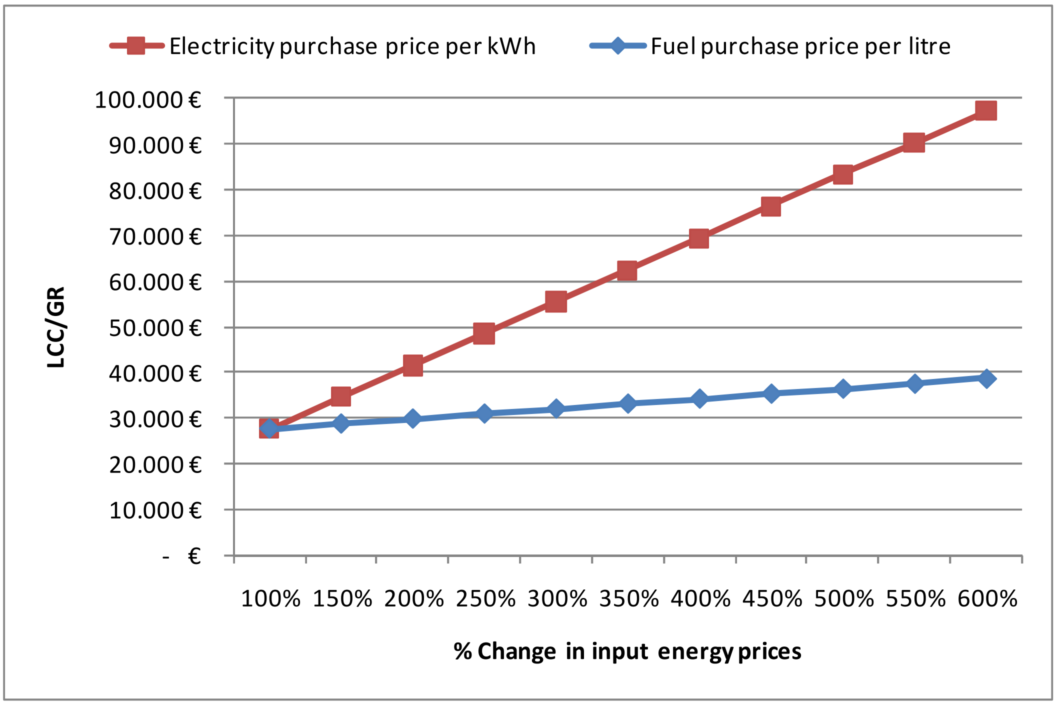

Figure 7-6: Variation in LCC value versus change in energy prices for B-a-U case

A third sensitivity analysis was carried out where the cost escalation factor is maintained at an annual rate of 2% but the energy prices are subject to less subsidies. Figure 7-6 depicts the change in the LCC value resulting from the increased values of each of electricity and fuel prices. It is obvious that electricity plays a bigger role in influencing the operation cost in case of a resort. Assuming the level of subsidy is reduced and the new tariffs for both electricity and fuel are 0.13 €/kWh & 0.5 €/l respectively, the resulting LCC would increase by 166% reaching a value of 73,260 €/GR.

7.2 REM for the design Alternatives 1

Alternative 1 is characterised by using RET in supplying electrical energy in addition to reducing the electrical energy demand through the implementation of energy efficiency measures as indicated in section 5.4.2. The following items have been taken into consideration during the calculation of the capital and operational costs:

- **Building works including walls and glazing:** Double insulated brick walls are used in addition to double glazing for all facades of the resort.
- **Sewage network:** A decentralized waste water treatment is used requiring a smaller sewage network; a sewage network size of 60% of that in the B-a-U case is assumed.
- **Electrical installations:** The main element considered in the capital investment costs is the transformers with a total capacity of 2 MW.
- **RET technology:** WECS, PV and a combination of WECS & PV are used in different scenarios.
- **Central air conditioning:** A smaller air cooled central air conditioning system is used for the public areas and 130 guest rooms; 90% of that of the B-a-U capital investment is assumed.
- **Split unit air conditioning:** The remaining 214 guest rooms are cooled using split air conditioning units but with smaller capacities due to the energy efficiency measure taken; 90% of that of the B-a-U capital investment is assumed.
- **Steam boilers:** No changes from the B-a-U case.
- **Landscape lighting: S**olar lamps are assumed with a capital investment twice that of the B-a-U case.
- **Seawater desalination plant:** A smaller RO system with a capacity of 400 m3/day is assumed.
- **Waste water treatment plant:** A decentralised constructed wetland system is used with a capacity of 320 m3/day.

7.2.1 Total capital investment for Alternatives 1

The costs of the modified and newly introduced items are based on market prices which the author acquired through internet research and estimation prices quoted by suppliers. For example, prices for building material such as bricks and glazing are the local market prices in Egypt while prices of WECS and PV are based on the results of internet research as indicated in sections 3.3.1 & 3.3.2. Table 7-3 shows the TCI for the 3 options developed in Alternative 1 where the cost per GR is Euro 26,145, 39,188 & 31,787 for Alternatives 1-a, 1-b & 1-c respectively.

Pos	Item	Cost (Euro)		
		Alternative 1-a	Alternative 1-b	Alternative 1-c
1	Building works	599,210		
2	Sanitary & Fire Fighting Works	86,806		
3	Electrical Works	73,334		
4	Air Conditioning	1,294,285		
5	Steam boilers	293,779		
6	Landscape	133,334		
7	Desalination Station	600,000		
8	Waste Water Treatment Station	600,000		
9	Renewable energy technology, RET	5,313,000	9,800,00	7,254,000
	Total Capital Investment, TCI	**8,993,748**	**13,480,748**	**10,934,748**
	TCI per GR	**26,145**	**39,188**	**31,787**

Table 7-3: Capital investment costs of Alternative 1 options

7.2.2 Operation cost for Alternatives 1

Resource	Average Consumption Per GN/ Annual			Operation cost Per GN/ Annual (euro)		
	Alt. 1-a	Alt. 1-b	Alt. 1-c	Alt. 1-a	Alt. 1-b	Alt. 1-c
Electricity, kWh	22.42/ 5,206,975	23,54/ 5467,261	22,23/ 5,163,347	0.78/ 182,244	0.82/ 191,354	0.78/ 180,717
Fuel, litre	2.43/ 564,455			0.27/ 62,090		

Table 7-4: GN and annual consumption and operation costs for Alternative 1 options

Based on the rates of consumption indicated in section 5.4.2 and the same tariffs used for the B-a-U case evaluation: 0.035 €/kWh & 0.11 €/l for electricity and fuel respectively, the operation costs for Alternative 1 options are calculated and presented in Table 7-4. It is noted that operation cost of Alternatives 1-a with WECS & 1-c with combined WECS& PV are almost the same while that of Alternative 1-b with PV only is slightly higher.

7.2.3 Maintenance & salvage costs for Alternatives 1

Following the same assumptions of the B-a-U case, the annual M&R cost and the total salvage costs are taken 2% & 5% of the total capital investment, respectively.

7.2.4 Revenues & benefits for Alternatives 1

Adopting RE in the project provides the opportunity to generate income by selling the generated electricity by RET into the grid at a defined feed-in tariff, if available. Up-to-date, there is no feed-in law established in Egypt and, therefore, to establish a better understanding of the impact of having a feed-in law, the two settings of no feed-in law and feed-in law will be run by the REM analysis. The first setting, *no feed-in law*, assumes that the existing condition where no feed-in tariff is available and any surplus in the energy produced will be sold to a neighbouring resort or establishment at the same tariff of 0.035 €/kWh as charged by the government. The second setting, *feed-in law*, assumes the existence of a feed-in law and that the feed-in tariff is 0.1 €/kWh for all renewable energies. The value of 0.1 €/kWh is chosen by the author following the lead of the feed-in law decreed by the Algerian government (Gipe).

Additional benefit can be gained by participating in the CDM programme where the CER certificates can generate an annual income. It is important to keep in mind that this added benefit does not significantly alter the financial performance of a project but acts rather like an additional bonus. Under the CDM programme, the total equiv. CO_2 emissions of the B-a-U case are compared to that of the proposed Alternatives and in case of achieving a saving in the emissions, CER are issued and can be traded generating this additional revenue.

7.2.5 REM Inputs for Alternatives 1

Input parameter	**Alternative 1-a**	**Alternative 1-b**	**Alternative 1-c**
Av. Annual occupancy	100%		
Guest to room ration	1.85		
Average electricity consumption	34.77 kWh/GN		
Average fuel consumption	2.43 l/GN		
Annual amount of RET produced electricity	3,552,798 kWh	3,963,138 kWh	3,745,277 kWh
Annual amount of RET produced thermal energy	0 kWh	0 kWh	0 kWh

Table 7-5: REM technical input parameters for Alternative 1 options

The REM technical & economic input parameters for the different options of Alternative 1 are listed in Table 7-5 & Table 7-6 respectively. The electricity consumption value and TCI as well the amount of RET generated electricity are the only parameters differing from the B-a-U case.

Input parameter	Alternative 1-a	Alternative 1-b	Alternative 1-c
Equity ratio, ER	30%		
Cost of finance, Rd	5.5%		
Expected return on equity Re	15%		
Term of loan, ToL	10 years		
Cost escalation factor	2%		
Total capital investment, TCI	€ 8,993,748	€ 13,480,748	€ 10,934,748
Project life time	25 years		
O&M cost as percentage of TCI	2%		
Electricity purchase price	0.035 €/kWh		
Fuel purchase price	0.11 €/kWh		
Salvage cost as percentage of TCI	5%		

Table 7-6: REM economical input parameters for Alternative 1 options

7.2.6 REM Outputs for Alternatives 1

The three setting outlined in section 6.2.4 are run through the REM tool:

1. No feed-in law: This is the case where only surplus of produced renewable power is sold at the same electricity purchasing price, 0.035 €/kWh.
2. CER benefit + No feed-in law: Similar to the previous scenario in addition to revenue generated from trading CER at 16 €/tCO_2.
3. Feed-in law: A feed-in law is assumed where all the power produced by RET is sold at the feed-in tariff of 0.10 €/kWh and the resort's power demand is consumed from the grid at the electricity purchase price of 0.035 €/kWh. It is assumed that both the feed-in tariff and electricity purchase price are subject to an annual cost escalation of 2%.

The REM results: LCC per GR, equiv. CO_2 emissions per GN and total annual CO_2 emissions are presented in Table 7-7. It is noted that Alternative 1-a with the wind energy solution has the lowest LCC while Alternative 1-b with the PV has the highest LCC. It is also observed that having the benefit of CER revenue lowers the LCC by ca. 4% while introducing the feed-in tariff reduces the LCC by ca. 17%.

The CO_2 emissions in Alternative 1 decrease to an average value of ca.4600 tonnes CO_2 equiv. Per annum achieving an average reduction of 43% with respect to the B-a-U case.

Scenario	Alternative 1-a	Alternative 1-b	Alternative 1-c
1. No feed-in law:			
LCC/GR	€ 38,126	€ 52,712	€ 44,417
2. CER + No feed-in law:			
LCC/GR	€ 36,429	€ 51,015	€ 42,720
3. Feed-in law:			
LCC/GR	€ 28,890	€ 43,525	€ 35,734
Emissions tCO_2/GN	19.62	20,28	19.51
Emissions tCO_2/year	4,557	4,710	4,531

Table 7-7: REM output for Alternative 1 options

Out of the three options, Alternative 1-c is chosen for further analysis as representative of Alternative 1 since it combines more than one source of RE and, hence, is considered to be more reliable in terms of bad weather conditions on some days of the year and would decrease the dependency on power supplied by the grid.

7.2.7 Sensitivity analysis for Alternative 1-c

Following the same steps in the B-a-U case, a sensitivity analysis is first carried out on the financial parameters of the project to identify their impact on the LCC value as follows:

- Equity ratio was varied from 30% to 100%
- Cost of finance, Rd, was varied from 5% to 8%.

The change in the resulting WACC causes a variation of the LCC from 44,741 €/GR to 40,926. With a 100% equity share the LCC reduces by 9%. Meanwhile, maintaining the same equity ratio of 30% and increasing the cost of finance to 8% results in a reduction of ca. 4% in the LCC. A table with detailed results of the sensitivity analysis is attached in the appendices.

A sensitivity analysis was carried out for the first setting, no feed-in law, on the LCC value by varying the cost escalation factor from 2% to 8%, reflecting the global annual increase in energy prices. The resulting change in the LCC is shown on Figure 7-7 where it can be observed the LCC increases from 44,417 to 56,901 €/GR. For example, should the annual cost escalation be 5% over the life time of the project, the LCC increases by ca. 11% reaching 49,405 €/GR.

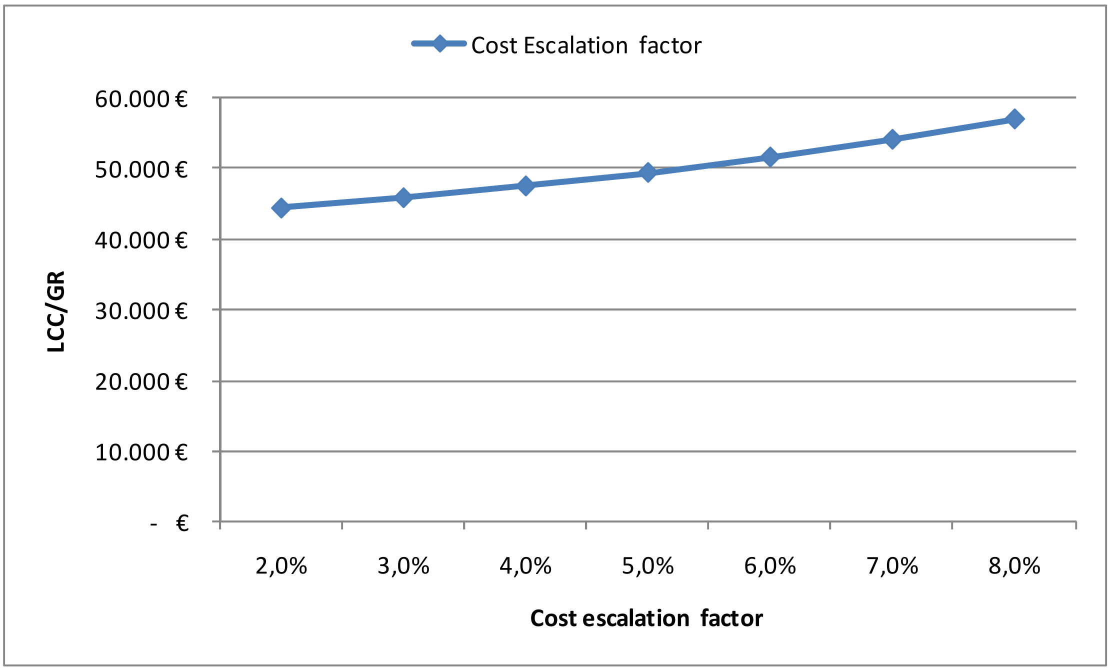

Figure 7-7: Variation in LCC value versus cost escalation factor for Alternative 1-c, no feed-in scenario

On the other hand, assuming the cost escalation factor is maintained at an annual rate of 2% and the energy prices are subject to less or no subsidies, the LCC increases by 51% up to 66.946 €/GR in case of a tariff of 0.13 €/kWh & 0.50 €/l for electricity and fuel respectively. The sensitivity analysis carried out on each of the electricity and fuel prices shows that the LCC is more influenced by the change in the electricity price than by that in the fuel price (see Figure 7-8).

A sensitivity analysis was carried out on the second setting, CER benefit + No feed-in law, in order to determine the impact of the CER trading price on the LCC. The results show that the impact is small compared with energy prices. For instance, an increase in the CER price by 50% will lead to a reduction in the LCC by 2% only and vice versa (see Figure 7-9).

Figure 7-8: Variation in LCC value versus change in energy prices for Alternative 1-c

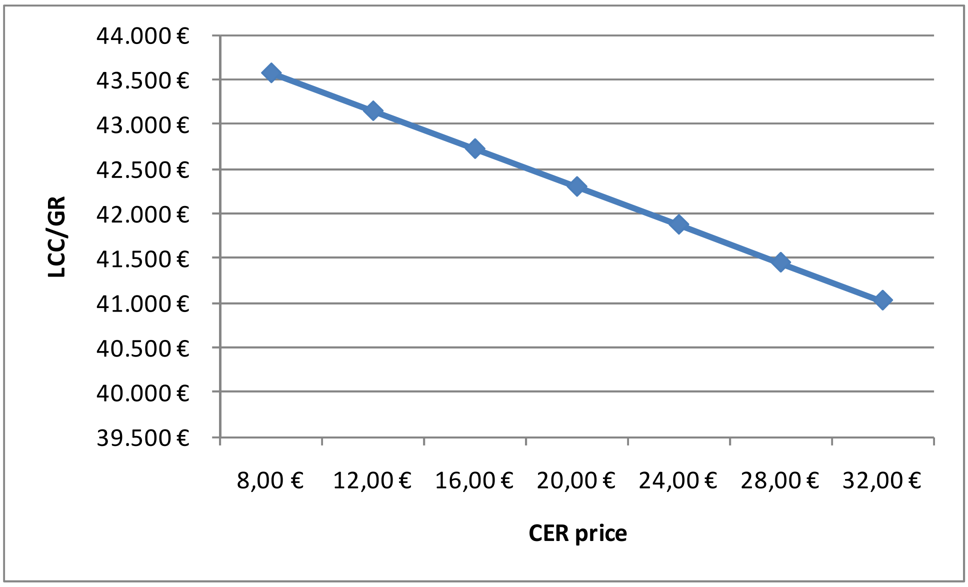

Figure 7-9: Influence of the CER price on the LCC for Alternative 1-c

7.3 REM for Alternatives 2 & 3

The main characteristic of both of those alternatives is using RE for producing both electrical and thermal energy. The RETs used in both alternatives are significantly different, yet the total energy and economic performances of both designs are comparable.

Alternative 2 is based on Alternative 1-c, using WECS & PV for the electricity part in addition to using solar collectors for supplying thermal energy while Alternative 3 uses mainly CSP to cover the electrical and thermal energy demand in addition to a part of PV modules.

7.3.1 Total capital investment for Alternatives 2 & 3

Based on the configuration explained under sections 5.4.3 & 5.4.4 and the market prices mentioned earlier under section 3.3, the TCI for both alternatives are calculated and presented in Table 7-8-

Pos	Item	Cost (Euro)	
		Alternative 2	Alternative 3
1	Building works	599,210	
2	Sanitary & Fire Fighting Works	86,806	
3	Electrical Works	73,334	56,667
4	Air Conditioning	1,294,285	1,330,638
5	Steam boilers	406,739	81,632
6	Landscape	133,334	
7	Desalination Station	600,000	

8	Waste Water Treatment Station	600,000	
9	Renewable energy technology, RET	7,254,000	9,074,950
	Total Capital Investment, TCI	**11,047,708**	**12,563,237**
	TCI per GR	**32,115**	**36,521**

Table 7-8: Capital investment costs for Alternatives 2 & 3

7.3.2 Operation cost for Alternatives 2 & 3

Based on the consumption calculations carried out in chapter 5 for Alternatives 2 & 3, Table 7-9 shows the computed operation costs. It is obvious that the power consumption and cost in Alternative 3 are significantly less, by ca. 58% from those of Alternative 2 while the fuel consumption in Alternative 3 is still less but only by ca. 24% from that of Alternative 2.

Resource	**Average Consumption Per GN/ Annual**		**Operation cost Per GN/ Annual (euro)**	
	Alternative 2	**Alternative 3**	**Alternative 2**	**Alternative 3**
Electricity, kWh	22.23/ 5,163,347	9,43/ 2,190,000	0.78/ 180,717	0.33/ 76,650
Fuel, litre	0.62/ 144,540	0.47/ 108,375	0.07/ 15,899	0.05/ 11,921

Table 7-9: Consumption & operation costs for Alternatives 2 & 3

7.3.3 Maintenance & salvage costs for Alternatives 2 & 3

Following the same previous assumptions in the B-a-U case and Alternative 1, the annual maintenance & replacement cost and the total salvage costs are taken 2% & 5% of the total capital investment, respectively.

7.3.4 Revenues & benefits for Alternatives 2 & 3

The same assumptions of feed-in tariff, CER benefits and settings adopted in Alternative 1 are applied for the analysis of Alternatives 2 & 3.

7.3.5 REM Inputs for Alternatives 2 & 3

The REM technical & economic input parameters for Alternatives 2 & 3 are listed in Table 7-10 & Table 7-11 respectively. The value of the parameters related to consumption, RET generated energy and the TCI of each of the alternatives differentiate them from each other otherwise the remaining input parameters remain unchanged.

Input parameter	Alternative 2	Alternative 3
Av. Annual occupancy	100%	
Guest to room ration	1.85	
Average electricity consumption	34.77 kWh/GN	25,93 kWh/GN
Average fuel consumption	0.62 l/GN	0.47 l/GN
Annual amount of RET produced electricity	3,745,255 kWh	4,523,500 kWh
Annual amount of RET produced thermal energy	460,000 kWh	15,300,800 kWh

Table 7-10: REM technical input parameters for Alternatives 2 & 3

Input parameter	Alternative 2	Alternative 3
Equity ratio, ER	30%	
Cost of finance, Rd	5.5%	
Expected return on equity Re	15%	
Term of loan, ToL	10 years	
Cost escalation factor	2%	
Total capital investment, TCI	€ 11,047,708	€ 12,563,237
Project life time	25 years	
O&M cost as percentage of TCI	2%	
Electricity purchase price	0.035 €/kWh	
Fuel purchase price	0.11 €/kWh	
Salvage cost as percentage of TCI	5%	

Table 7-11: REM economical input parameters for Alternatives 2 & 3

7.3.6 REM outputs for Alternatives 2 & 3

The same previous three defined settings are run by the REM for each of the alternatives 2 & 3 where the REM results are presented in Table 7-12. It is interesting to observe that both solutions although are based on different energy design concepts and technologies, yet, their LCC seem to very close. The additional benefit of CER revenue lowers the LCC by 5% & 7% in Alternatives 2 & 3 respectively while having a feed-in tariff reduces the LCC by 14% &

16%. However, it can be noted that in the setting of feed-in law, the LCC seem to be more affected in Alternative 3 where it breakevens with that of Alternative 2.

Scenario	Alternative 2	Alternative 3
1. No feed-in law:		
LCC/GR	€ 43,149	€ 44,571
2. CER + No feed-in law:		
LCC/GR	€ 40,908	€ 41,438
3. Feed-in law:		
LCC/GR	€ 34,467	€ 34,084
Emissions tCO_2/GN	14.75	6,79
Emissions tCO_2/year	3,427	1,577

Table 7-12: REM output for Alternatives 2 & 3

Both alternatives show a reduction in the CO_2 emissions, yet, Alternative 3 shows the greatest reduction compared with all the other alternatives reaching am amount of 6,499 tonnes/year of avoided CO_2 emissions with respect to the B-a-U case.

7.3.7 Sensitivity analysis for Alternative 2

The sensitivity analysis carried out on the equity ratio and cost of finance did not show any major variance to the previous results of Alternative 1-c. For example, a 100% equity share resulted in a reduced LCC by 7% while a cost of finance 8% reduces the LCC by 4%.

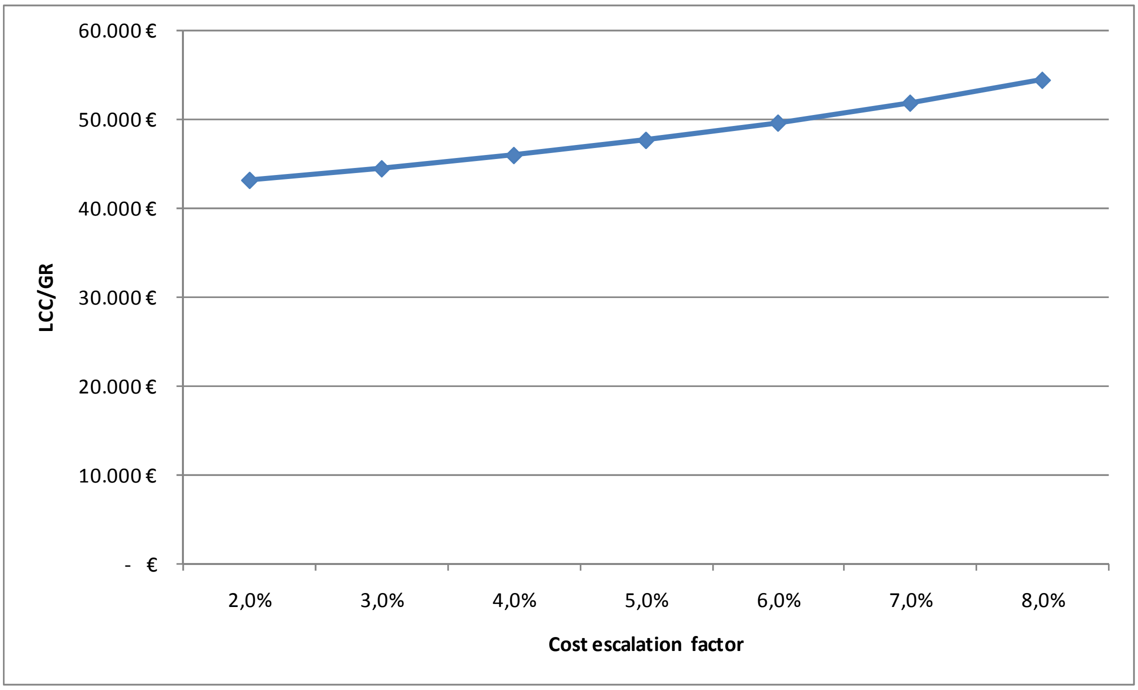

Figure 7-10: Variation in LCC value versus cost escalation factor for Alternative 2, no feed-in scenario

The sensitivity analysis carried out on the setting, no feed-in law, shows a variation in the LCC from 43,149 to 54,336 €/GR (Figure 7-10). For example, the cost escalation factor of 5% will lead to an increase in the LCC by ca. 10%.

On the other hand, the sensitivity analysis carried out on the energy prices show that fuel has a minor influence on the LCC value versus electricity which is due to the reduction in fuel consumption resulting from using solar thermal energy (Figure 7-11). The analysis also shows that at tariff of 0.13 €/kWh & 0.50 €/l for electricity and fuel respectively and annual cost escalation factor of 2%, the LCC increases by 39% to 59,838 €/GR.

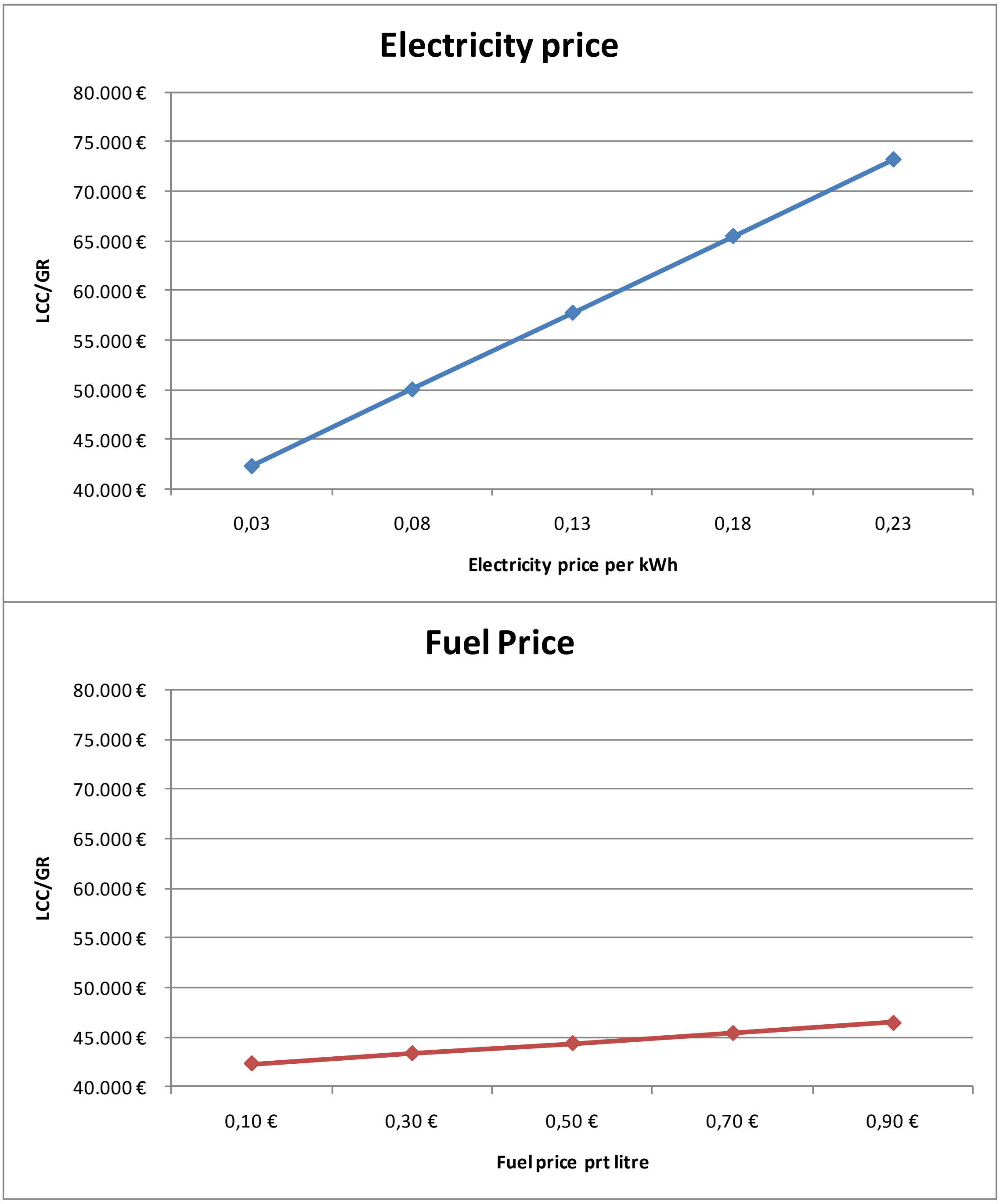

Figure 7-11: Variation in LCC value versus change in energy prices for Alternative 2

The sensitivity analysis carried out on the second setting, CER benefit + no feed-in law, which determines the impact of the CER trade price on the LCC, shows that an increase in the CER price by 50% will lead to a reduction in the LCC by 2.74% and vice versa (Figure 7-12).

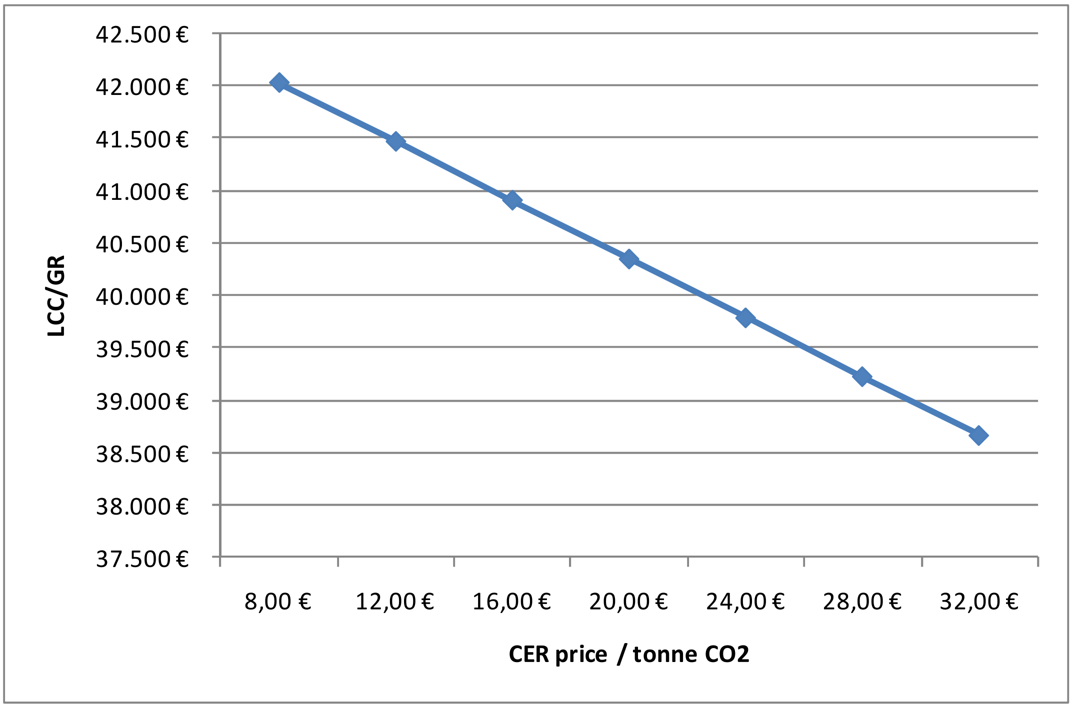

Figure 7-12: Influence of the CER price on the LCC for Alternative 2

7.3.8 Sensitivity Analysis for Alternative 3

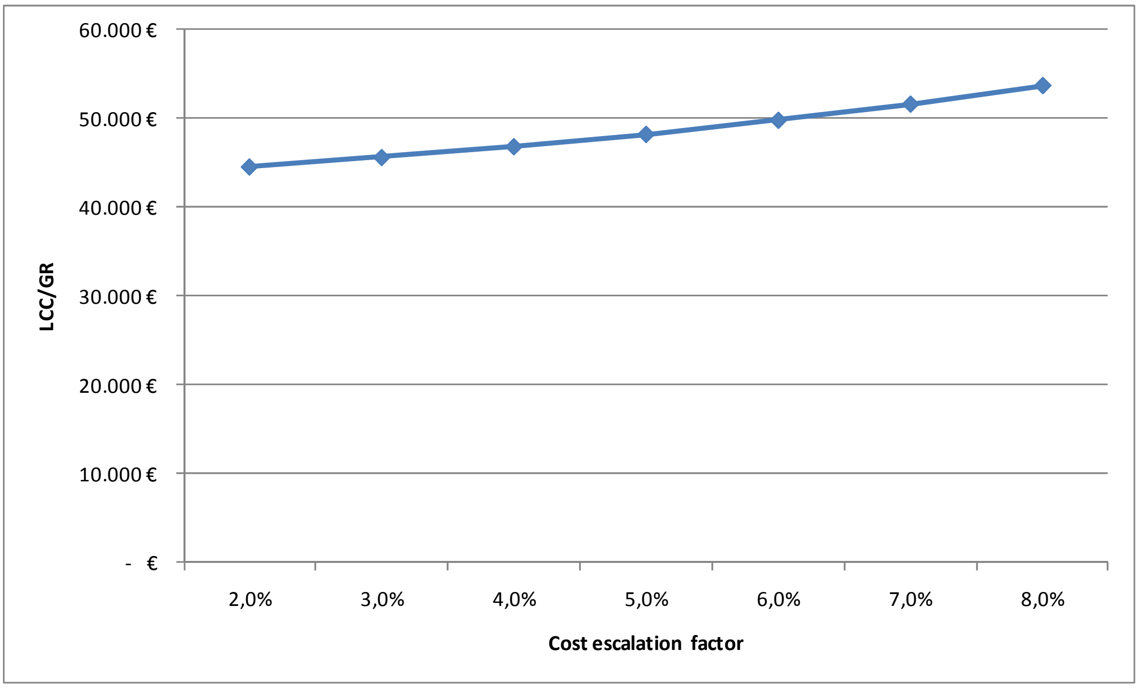

Figure 7-13: Variation in LCC value versus cost escalation factor for Alternative 3, no feed-in scenario

The sensitivity analysis carried out on the equity ratio and cost of finance did not show any major variance to the results of the previous alternatives. An equity share of 100% results in a reduced LCC by 3%, while a share of 30% and an 8% cost of finance, the LCC reduces by 2%.

The sensitivity analysis carried out on the first setting 1, no feed-in law, shows a variation in the LCC from 44,571 to 53,684 €/GR (Figure 7-13). The cost escalation factor of 5% will lead to an increase in the LCC by ca. 8.2%.

Similar to Alternative 2, the sensitivity analysis carried out on the energy prices shows that in Alternative 3 the fuel has nearly no major influence on the LCC value which is due to the very low fuel consumption resulting from having a renewable share of 94% in thermal energy part (Figure 7-15). The analysis also shows that at tariff of 0.13 €/kWh & 0.50 €/l for electricity and fuel respectively and at annual cost escalation factor of 2%, the LCC increases by 50& to 51,157 €/GR.

The sensitivity analysis carried out on the second setting, CER benefit + no feed-in law, in order to determine the impact of the CER trade price on the LCC shows that an increase in the CER price by 50% will lead to a reduction in the LCC by 3.78% and vice versa (Figure 7-14).

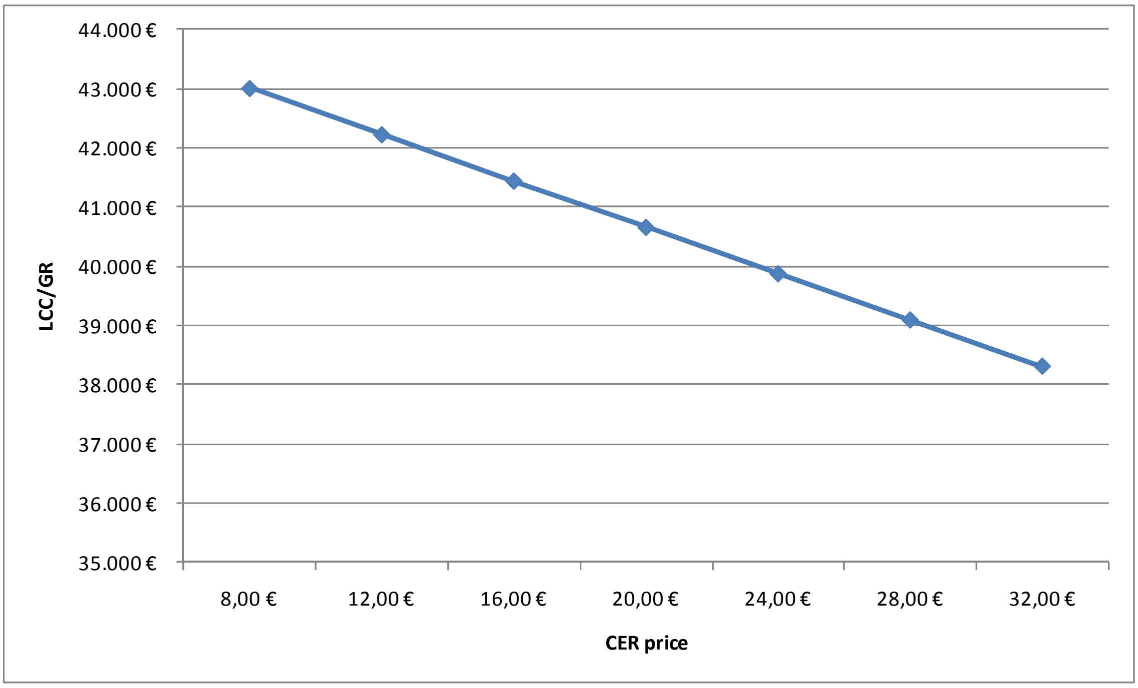

Figure 7-14: Influence of the CER price on the LCC for Alternative 3

Figure 7-15: Variation in LCC value versus change in energy prices for Alternative 3

7.4 Discussion of REM results

7.4.1 Summary of REM input and output parameters for the B-a-U and solar alternatives

In this section an overview of the technical and economical performances of all design alternatives are presented and compared to that of the B-a-U case as illustrated in Table 7-13. The first half of the table summarises all the input parameters used in the REM analysis while the second half presents the outputs of the REM. The electricity demand in Alternatives 1-c & 2 are lower from that of the B-a-U case as a result of the energy efficiency measures taken while that of Alternative 3 has the lowest value as a result of switching to solar cooling system. On the other hand, the thermal energy demand decreases significantly in Alternative 2 mainly due to switching to solar heating for the DHW and swimming pool while it becomes the highest value in Alternative 3 as a result of using a solar cooling system which depends on thermal energy. However, as the renewable fraction increases from one alternative to the next, the fuel consumption consequently decreases and becomes the lowest in Alternative 3 reaching 0.47 compared to 2.43 l/GN of B-a-U case.

Item	**B-a-U case**	**Alternative 1-c**	**Alternative 2**	**Alternative 3**
Average GN electricity demand, kWh	48.1	34.77 (72%)	34.77 (72%)	25.93 (54%)
Annual electricity demand, MWH	11,173	8,077 (72%)	8,077 (72%)	6,023 (54%)
Annual RET produced electricity, MWh	0	3,745	3,745	4,524
Annual non-RET produced electricity, MWH	11,173	5,163 (46%)	5,163 (46%)	2,190 (20%)
Average GN thermal demand, kWh	22.09	22.09 (100%)	7,64 (35%)	31.23 (141%)
Annual RET produced thermal energy, MWh	0	0	0.46	15,301
Annual non-RET produced thermal energy, MWH	5.131	5.131 (100%)	1.314 (26%)	0.985 (19%)
Annual fuel consumption, litre	564,455	564,455 (100%)	144,540 (26%)	108,375 (19%)
Average GN fuel consumption, litre	2.43	2.43	0.62	0.47
Annual Surplus in RET produced electricity, kWh	0	831,177	831,177	691,000
Annual equiv. CO_2 emissions, tonnes	8,077	4,531 (56%)	3,427 (42%)	1,577 (20%)
Average GN equiv. CO_2 emission, kg	34.77	19.51	14.75	6.79
Total capital investment per GR	€ 9,482	€ 31,787 (335%)	€ 32,115 (339%)	€ 36,521 (385%)
Total capital investment (thousands)	€ 3,385	€ 10,935	€ 11,047	€ 12,563

Item	B-a-U case	Alternative 1-c	Alternative 2	Alternative 3
Annual M&R cost	€ 67,710	€ 218,695	€ 220,954	€ 251,265
Annual operation cost (electricity & fuel)	€ 509,008	€ 344,801 (68%)	€ 298,610 (59%)	€ 222,709 (44%)
Salvage cost	€ 169,276	€ 546,737	€ 552,385	€ 628,162
Annual revenue from surplus electricity sales	€ 0	€ 29,091	€ 29,091	€ 24,185
Annual CER benefit	€ 0	€ 56,319	€ 74,401	€ 103,991
LCC per GR, no feed-in law	**€ 29,546**	**€ 44,417 (150%)**	**43,149 (146%)**	**44,571 (151%)**
LCC per GR, no feed-in law incl. CER benefit	**€ 29,546**	**€ 42,720 (145%)**	**40,908 (138%)**	**41,438 (140%)**
LCC per GR, feed-in law	**€ 29,546**	**€ 35,734 (121%)**	**34,467 (117%)**	**34,084 (115%)**
Annual avoided CO_2 emissions, tonnes	**_**	**3,520**	**4,650**	**6,499**
Electricity renewable fraction	**_**	**36%**	**36%**	**64%**
Thermal renewable fraction	**_**	**0%**	**26%**	**86%**
Overall renewable fraction	**_**	**30%**	**35%**	**70%**

Table 7-13: Overview of the REM analysis for B-a-U and design alternatives; consumption and cost percentages are calculated with respect to the B-a-U case

It should also be noted that on considering the TCI only for comparing the different alternatives, the difference in the TCI value of the solar alternatives is very high reaching 285% of that B-a-U while on considering the LCC, the difference is only 50% of that of the B-a-U. This emphasises the importance of using LCC or ELCC in decision making rather than the TCI as commonly adopted.

Three values of renewable fraction for the resort are calculated and presented. Only the actual consumption is taken into consideration. Any surplus energy is not considered as it is not consumed by the same resort. The three versions are explained as follows:

- **Electricity renewable fraction** which is the amount of consumed RET electricity divided by the total electricity demand by the resort.
- **Thermal renewable fraction** which is the amount of consumed RET thermal energy divided by the total thermal energy demand by the resort.

- **Overall renewable fraction** which is the amount of operation cost savings as a result of using RETs divided by the total operation cost of the resort. The overall renewable fraction reflects the combined effect of thermal and electrical renewable fractions.

From the technical aspect, Alternative 3 seems to offer the lowest consumptions of electrical and thermal energy, the lowest CO_2 emissions and the highest renewable fractions. However, from the economical aspect, although Alternative 3 has the highest capital investment cost, yet the three solar alternatives have a very close value of LCC. It is also noticed that the more there is potential to generate revenue from CER benefits or having a feed-in law system, the more the LCC value decreases. For example, in the feed-in law setting the reduction in the LCC is 24% for Alternative 3 and 20% for Alternative 2 with respect to current setting of no feed-in law.

Table 7-14 summarised the results of the sensitivity analysis carried out in the previous sections of this chapter. Comparing the four design alternatives, it can be observed that the higher the TCI is, the less the LCC is affected by change in the equity share and/or the cost of finance. For example, while the increase in cost of finance leads to an increase of 10% in the LCC of the B-a-U case, the LCC of Alternative 3 increases by 2% only.

The higher the renewable fraction is, the lower the impact of the cost escalation on the LCC is which can be attributed to the lower dependency on fossil fuel. An annual cost escalation of 5% will lead to an increase in the LCC by 14% in case of the B-a-U while 8% only in the case of Alternative 3. Similarly, the higher the energy prices are, the lower the LCC is impacted in case of the solar alternatives. At a tariff of 0.13 €/kWh & 0.5 €/l for electricity and fuel respectively, Alternative 3 has a much lower change in the LCC (+13%) compared to the rate of change in the B-a-U case where the LCC increased by 62%.

Scenarios	**B-a-U case**		**Alternative 1-c**		**Alternative 2**		**Alternative 3**	
	Euro	%	Euro	%	Euro	%	Euro	%
Equity 30%, Rd 5%	28,110	-	44,741	-	43,420	-	44,730	-
Equity 30%, Rd 8%	25,167	-10%	43,069	-4%	42,034	-3%	43,944	-2%
Equity 100%	20,893	-26%	40,926	-9%	40,321	-7%	43,172	-3%
Cost escalation 5%	33,562	+14%	49,406	+10%	47,6431	+9%	48,212	+8%
EPP@ 0.13 €/kWh, FPP@ 0.5 €/l	73,260	+62%	66,946	+34%	59,838	+28%	51,157	+13%
CER price +50% **-50%**	_	_	41,872/ 43,568	-2% +2%	39,787/ 42,029	-3% +3%	39,871/ 43,004	-4% +4%

Table 7-14: Overview of the variance in the LCC/GR value with respect to changes in the original input parameters.

In the second setting where CER trading is applied, the results show that the change in the CER trading price have a minor impact on the LCC value which varies by 1% only in all the of the solar alternatives.

The impact of the TCI on the LCC is examined as shown on Figure 7-16. In case of the B-a-U, the impact of change in the TCI remains the same along the three different settings. In case of the solar alternatives, the impact of TCI on the LCC increases as the revenues increases and the resulting LCC decreases. For example, in Alternative 3, an increase of 5% in the TCI results in an increase of the LCC by 4.74%, 5.1% and 6.2% for settings 1 to 3 respectively. It is also observed that the higher the TCI is, the higher the rate in the change of the LCC would be. A 5% change in the TCI of B-a-U case leads to a 2% change in the LCC while for Alternatives 1-c, 2 & 3 the change in the LCC is 4.14%, 4.31% & 4.74% respectively. In case of consistency in the assumptions made for calculating the TCI, the impact of TCI on the LCC and decision making is minor since the objective is to compare alternatives. However, it is always recommended to run different scenarios of the TCI in order to be able to define the level of risk involved.

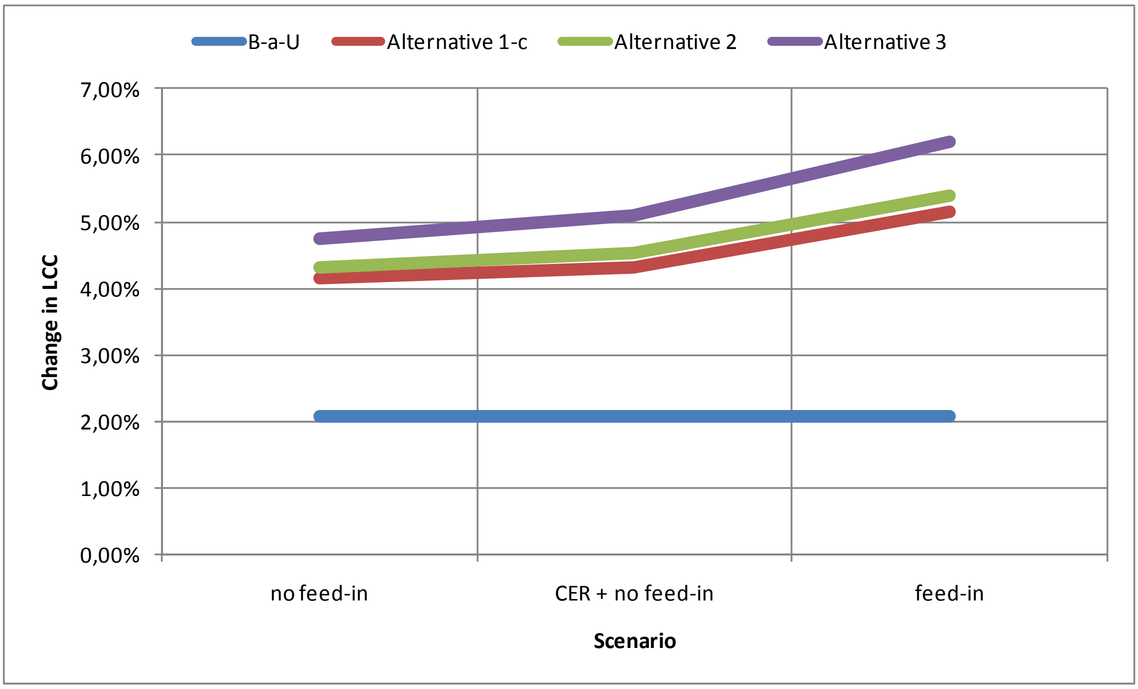

Figure 7-16: Impact of 5% change in TCI on the LCC value

Studying the detailed results of the sensitivity analysis tables for the different alternatives, the author sought to indentify at which energy prices would the LCC of the B-a- U case start to breakeven with that of the solar alternatives. In this case, all original input parameters are maintained the same except for the energy prices which are variable and defined as EPP & FPP for the electricity and fuel purchase price per unit respectively.

Table 7-15 is a matrix showing the approximate values of the energy prices at which the LCC of one alternative breakevens with the other. The B-a-U case would start to breakeven with Alternative 3 at an EPP of 0.08 €/kWh and an FPP of 0.3 €/l. As Alternative 2 has a higher fuel consumption compared to Alternative 3, the breakeven point for the B-a-U would be at a higher FPP at 0.5 €/l. Alternative 1-c does not have any thermal renewable fraction and it can be noted that the breakeven point is dependent only on the EPP and occurs at 0.13 €/kWh. The matrix also shows the breakeven points among the solar alternatives themselves; for example Alternative 1-c breakevens with Alternative 3 at an EPP of 0.035 €/kWh and an FPP of 0.3 €/l which reflects the higher portion of thermal energy in Alternative 3.

	B-a-U case	**Alternative 1-c**	**Alternative 2**	**Alternative 3**
B-a-U case		EPP @ 0.13 €/kWh FPP@ 0.11 €/l	EPP @ 0.08 €/kWh FPP@ 0.5 €/l	EPP @ 0.08 €/kWh FPP@ 0.3 €/l
Alternative 1-c	EPP @ 0.13 €/kWh FPP@ 0.11 €/l		EPP @ 0.035 €/kWh FPP@ 0.11 €/l	EPP @ 0.035 €/kWh FPP@ 0.3 €/l
Alternative 2	EPP @ 0.08 €/kWh FPP@ 0.5 €/l	EPP @ 0.035 €/kWh FPP@ 0.11 €/l		EPP @ 0.035 €/kWh FPP@ 0.9 €/l
Alternative 3	EPP @ 0.08 €/kWh FPP@ 0.3 €/l	EPP @ 0.035 €/kWh FPP@ 0.3 €/l	EPP @ 0.035 €/kWh FPP@ 0.9 €/l	

Table 7-15: Breakeven value for the energy prices of different design alternatives

Another simulation was carried out assuming that the project would receive a funding grant of 20% of the TCI and generate revenues from CER trading in the case of no feed-in law. The resulting LCC is 32,579 €/GR which is comparable to that in the case of having a feed-in law.

7.4.2 Evaluation

7.4.2.1 The ELCC portfolio

The previously mentioned results show that with the current situation in Egypt the LCC of solar resorts are much higher than the B-a-U case. Even with adding CER benefits to the LCC, the situation improves slightly but does not differ greatly. On the other hand, should the energy tariffs be not greatly subsidised as the current case, the situation would have differed since the difference in the LCC value decreases. However, the objective is to achieve not only an economical solution but also environmental sustainability; therefore, one should not neglect the environmental part represented in the amount of CO_2 emissions. Figure 7-17 & Figure 7-18 present a graphical overview of all alternatives depicting both the economical and environmental performance of the resort for both scenarios: No feed-in law and feed-in law respectively. In the existing situation with no feed-in law, the environmental performance of the B-a-U is significantly lower than that of the three solar alternatives. Once a feed-in law is introduced or the energy prices are increased to the breakeven values, the economical performance of the solar resorts improves greatly and might be an attractive solution for the investors.

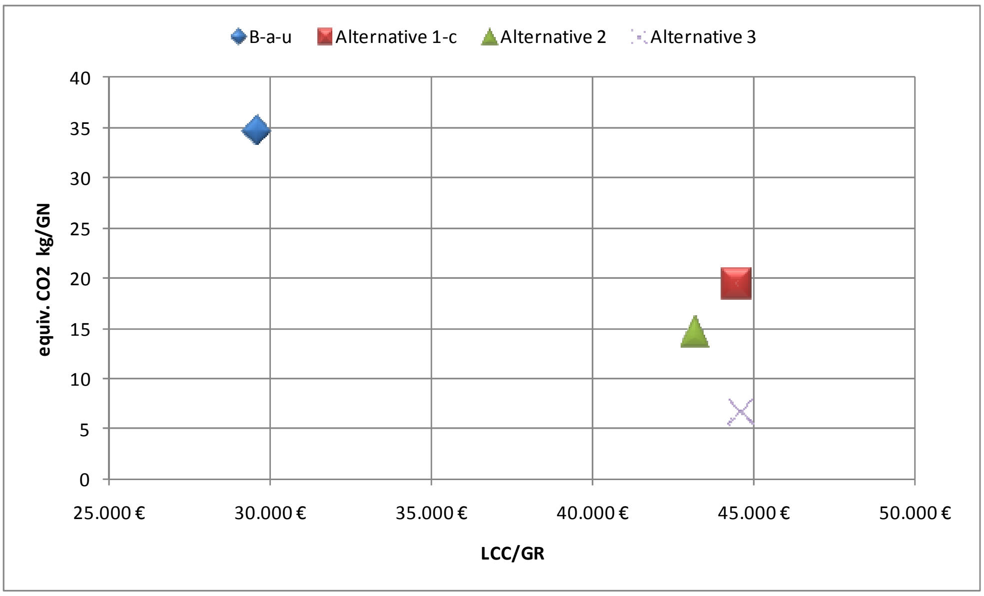

Figure 7-17: ELCC portfolio presentation of all design alternatives in no feed-in law scenario

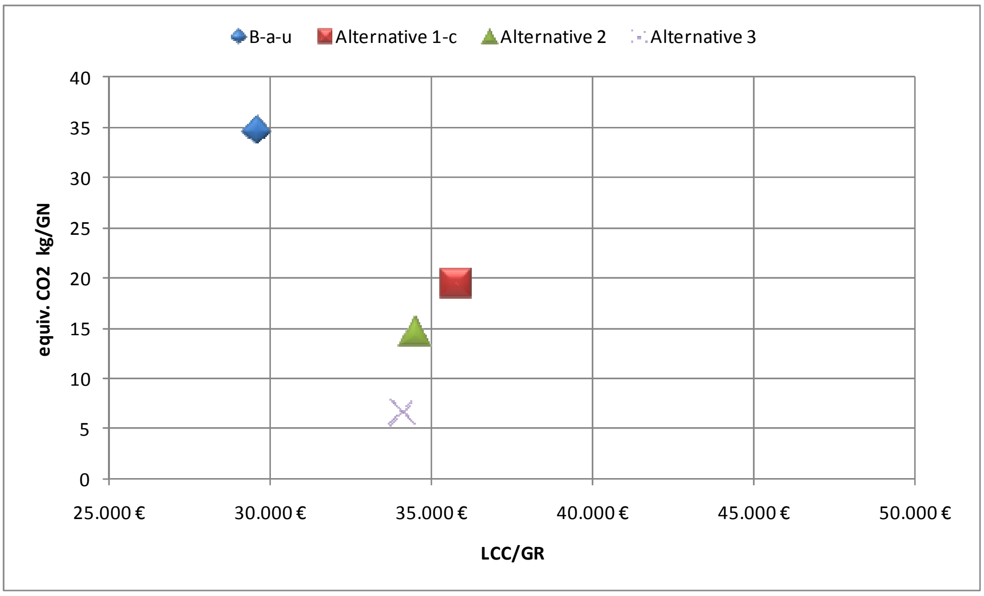

Figure 7-18: ELCC portfolio presentation of all design alternatives in feed-in law scenario

In the case of having a feed-in law and examining the three solar alternatives in Figure 7-18, Alternative 3 seem to be the most appropriate solution having the best economic and environmental performance among the three solar alternatives. Based on this conclusion, the author chose Alternative 3 for further economic evaluation versus the B-a-U case.

7.4.2.2 Simple payback period

The author in this step tries to determine the payback period considering the annual savings and benefits achieved with respect to the B-a-U case in a feed-in law scenario. The REM analysis tool is used based on the same previous assumptions and input parameters except for the costs are entered as incremental and/or saving values between both solutions. Table 7-16 shows the incremental values for the TCI, operation cost savings and revenues as well as the

REM results. The values expressed in brackets are savings achieved with respect to the B-a-U case. This analysis results in a PP of 18 years and a PI less than 1 which is a negative indication about the project profitability while the IRR is 4.2% less than the considered discount rate.

On the other hand if the feed-in tariff is kept at a value of 0.10 €/kWh together with the other input parameters except for introducing a fund grant of 30% of the TCI, the incremental LCC value becomes 2,369 €/GR after debt. The PP reduces to 13 years and the IRR would be in that case 8.8%; however, the PI would be 0.45 still less than 1.

Item	Alternative 3	B-a-U	Incremental/ (savings) value
Total capital investment	€ 12,563,237	€ 3,385,524	€ 9,177,713
Annual electricity operational costs	€ 210,788	€ 391,053	€ (180,266)
Annual fuel operational costs	€ 11,921	€ 62,090	€ (50,169)
Annual revenue from feed-in tariff	€ 452,350	€0	€ (452,350)
Incremental LCC/GR			€ 6,531
Simple payback period after debt service			18 years & 7 months
Profitability index, PI			0,67 < 1.0
IRR			4.2%

Table 7-16: Payback, PI and IRR considering the savings in Alternative 3 with respect to B-a-U with a feed-in tariff of 0.10 €/kWh

The same simulation is once more run but using a feed-in tariff of 0.20 €/kWh with the other input parameters remaining unchanged. Table 7-17 shows that the PP is then reduced to 10 years with a PI of 1.28 and an IRR increasing to 14.4%. It is noted that the incremental LCC value turns negative which means a positive NPV. All those economic indicators: PP, positive NPV, PI>1 and a high IRR suggests a favourable and positive economic performance of the proposed alternative under the defined conditions.

In conclusion, the ELCC analysis carried out within this chapter shows that although solar resorts can be technically implemented in Egypt, yet, financial incentives are required considering the prevailing conditions. Two strategies were also examined determining their influence on improving the potential of applying RE. The first incorporates decreasing or removing the energy subsidies together with introducing a feed-in law enabling SME to feed-in their RE generated power at appropriate prices. The second strategy is to provide financial grants to RE projects in order to improve their economical performance under the current energy prices.

Item	Alternative 3	B-a-U	Incremental/ (savings) value
Total capital investment	€ 12,563,237	€ 3,385,524	€ 9,177,713
Annual electricity operational costs	€ 210,788	€ 391,053	€ (180,266)
Annual fuel operational costs	€ 11,921	€ 62,090	€ (50,169)
Annual revenue from feed-in tariff	€ 452,350	€0	€ (904,700)
Incremental LCC/GR			€ (9,602)
Simple payback period after debt service			10 years & 7 months
Profitability indeed, PI			1.28 > 1.0
IRR			14.4%

Table 7-17: Payback, PI and IRR considering the savings in Alternative 3 with respect to B-a-U with a feed-in tariff of 0.20 €/kWh

8 Conclusions

The purpose of this chapter is to summarise the hypothesis and primary issues raised in this thesis, evaluate the main findings and discuss future works in this area of research in tourism economics and environment sustainability.

The thesis started with introducing the global energy problem and the world's increasing appetite for fossil fuels which is creating a compelling reason to make sound energy choices by switching to cleaner forms of energy. The world understands well that the use of fossil fuels has serious environmental consequences and that technology choices made today will have consequences well into the future. It is illustrated that the hotel industry is one of the major energy-consuming sectors and that there is a need to address not only energy efficiency but also energy resources used in the hotel sector.

With the major role played by tourism in the Egyptian economy and the increasing popularity of the Red Sea area in Egypt as a resort and holiday destination, a fast growing development of hotels and resorts is taking place in areas such as Sharm el Sheikh, Marsa Alam, Hurghada, Nabq, etc.. This will ultimately result in higher energy demand and, consequently, higher CO_2 emissions.

Both the Ministry of Tourism and Ministry of Environmental Affairs in Egypt are trying to promote sustainable tourism; however, there is great reluctance from tourism developers to adopt renewable energy technologies. The well known argument is the very high investments associated with renewable energy which reflects lack in environmental awareness.

It is, therefore, the objective of this thesis to investigate the energy, environmental and economic performances of the existing five stars resorts with conventional design versus a proposed solar design resort using different types of RETs. The town of Sharm el Sheikh was chosen for the study since it is a newly developed resort area and represents other areas in the Red Sea region which are under development and following the lead of Sharm el Sheikh being one of the most popular destinations in Egypt.

In order to understand the underlying circumstances in the hotel industry in Egypt and identify opportunities and concern issues, an overview on both the energy system and tourism sector is presented in chapter 2.

The first step in carrying out this research work was to perform a literature review on: Energy use in resorts and hotels; the extent of using solar concept in resorts; and types of renewable energy technologies. The goal was to identify and establish a benchmark for energy consumption in resorts which would be used together with the identified performance of solar concept and commercially available RETs in developing the proposed solar resort in Sharm el Sheikh. The literature review carried, out in chapter 3, has also helped in identifying the gaps and lack of information in the hotel industry, urging the need for more research in that field with regards to energy use and RET application.

The second step was to carry out a survey in Sharm el Sheikh, as described in chapter 4, targeting resorts classified as five stars in order to identify the business-as-usual resort criteria and its energy performance. The third step is presented in chapter 5 where the B-a-U design is further developed into several solar resort design alternatives using the value management techniques. In chapter 5, an analysis tool REM was developed for resort economic and environmental evaluation based on environmental life cycle costing methodology. Finally, all the developed design alternatives together with the B-a-U case are evaluated using the REM method.

The results of the survey and the developed solar design alternatives are summarised in the next sections.

8.1 Energy use in Sharm el Sheikh resorts

It was identified that out of a total of 126 resorts in Sharm el Sheikh, 29% of which are classified as five stars resorts according to the standards set by the Ministry of Tourism in Egypt. The survey carried out targeted those five stars resorts offering the same quality of service and having common facilities. Only 14 out of 36 resorts responded to the questionnaires and inquiry carried out by the author. However, only seven of those fourteen resorts provided adequate and consistent information that could be used. The other seven resorts did not have complete records of their energy consumptions and guest numbers.

The seven resorts that were analysed have a guest room number ranging from 210 to 835. All of them use electricity supplied by the network grid and diesel fuel in case of power cuts. Thermal energy required for domestic hot water and laundry steam is produced mainly by fuel operated boilers. Only one out of the seven resorts used solar thermal collectors for the supply of DHW. All resorts have their own reverse osmosis desalination and waste water treatment plants. None of the investigated resorts took any measures to reduce heat gain through the buildings envelope while one resort only used double glazing versus single glazing in the other six resorts. This indicated lack of environmental awareness and energy efficiency practices.

The guest to room ratio and room occupancy rates of the resorts vary from 1.8 to 2 and 70% and 90% respectively, indicating a high average occupancy throughout the year and non-seasonal operation.

The data gathered is based on monthly bills while daily and/or hourly consumptions were not available. Guest-night was chosen as an energy use intensity in analysing the energy consumptions of the resorts in order to reflect the extent of occupancy and guest numbers in the resort. The results show that the average consumptions per guest-night for electricity and fuel vary between 38 & 58 kWh and 1.5 & 3 litre respectively. Compared to guest-night power consumption in Europe and New Zealand, the consumption rates in Sharm el Sheikh lie with the same range while are considered to be high when compared to those of Cyprus and Majorca.

It was also identified that LPG is used as a third of source energy, specifically, for kitchen equipment. However, the extent of using LPG in the kitchen versus electricity varies widely from one resort to the other and no consumption pattern could be established. It was also concluded that the share of LPG in the energy mix is very low in terms of consumption and CO_2 emissions. Accordingly, LPG was not further considered in the REM evaluation.

Although the thesis focuses on energy consumption, nevertheless water consumption was also investigated since it plays a major role in power consumption since all resorts produce their fresh water consumption through their own reverse osmosis desalination plants. The guest-night consumption was found to range from 0.6 to 1 cubic meter. The WWF benchmark values for water consumption indicates excellent performance when considering Sharm el Sheikh as a tropical region and satisfactory in considering Sharm el Sheikh as a Mediterranean regions.

Finally, occupation versus consumption was investigated and it was identified that consumption per guest-night decreases with the increase in occupancy. It was also noted that the consumption rate per guest night does not alter much above occupancy of 80% while the rate of change increase enormously as the occupancy goes below 50%.

It was also identifies that for resorts with capacity ranging from 200 to 835 GR, the consumption rates do not alter greatly indicating that the room numbers have a minor influence on consumption for that range of resorts capacities.

These findings were then used in developing the different design alternatives and their consumption patterns.

8.2 Solar design alternatives

A business-as-usual case was first established based on the current practices adopted in design, implementation and operation of resorts in Sharm el Sheikh. The B-a-U case is used for comparison and evaluation of the proposed solar resort. The energy production system, demand and consumption were defined for each case. Based on the previously identified benchmark values for Sharm el Sheikh, energy efficiency targets were set for power, fuel and water consumption for the solar resort design.

Value management technique was used to develop the solar resort design alternatives by first identifying the functions in a resort and developing ideas which were consolidated into five alternative designs. The first three alternatives are based on renewable power production only: (1-a) WECS, (1-b) PV, and (1-c) WECS/PV. The last two alternatives include both renewable electrical and thermal energy: (2) WECS/PV/ solar collectors and (3) CSP/PV. The energy production system, demand and consumption for each alternative were, accordingly, worked out. In all alternatives, a renewable fraction of minimum 40% was set for the power production system. Grid electricity and fuel were used as a backup to meet energy demands during night, non-sunshine hours, and/or low wind speeds in order to be able to cover the whole energy demand of the resort.

Following the concept of value management, no economical evaluation is carried out at this stage rather technical evaluation only. Among the three first alternative where renewable energy is used only to provide electricity, Alternative 1-c was chosen for further analysis since it combines two types of renewable energy, WECS and PV, forming a more reliable solution. Three types of renewable energy production systems are compared: Power only, power & thermal, cogeneration of power and thermal represented in Alternatives 1-c, 2 & 3 respectively.

The calorific value of the total energy consumption for electricity and fuel was calculated 263.45, 215.46, 148.21, 110.81 MJ/GN for design options: B-a-U, Alternative 1-c, Alternative 2, and Alternative 3 respectively. Similarly, the CO_2 emissions were estimated at 34.77, 19.51, 14.75 & 6.79 kgCO_2/GN for B-a-U, Alternative 1-c, Alternative 2, and Alternative 3 respectively. It is observed that Alternatives 2 & 3 seem to have the best energy and environmental performances among the five design options with Alternative 3 being the best option. Alternative 2 consists of the energy mix: WECS, PV & solar collectors while Alternative 3 consists of the CSP and PV system.

8.3 Resort evaluation modelling

The REM model for resort evaluation is developed based on environmental life cycle costing and used for evaluating the B-a-U case and the solar design alternatives. The objective is to calculate the life cycle cost per guest room and the environmental performance expressed as equiv. CO_2 emissions per guest-night. The LCC is calculated by adding all present and future costs, revenues and savings discounted to the present time.

The results of the REM show that in the prevailing situation in Egypt, the B-a-U case has the lowest total capital investment and life cycle costs: 9,482 and 29,546 €/GR respectively while the highest equiv. CO_2 emissions of 34.77 kgCO_2/GN and zero renewable fraction. On the other hand Alternative 3, with the CSP system, has the highest capital investment and life cycle costs: 36,521and 44,571 €/GR respectively while the lowest equiv. CO_2 emissions of 6.9 kgCO_2/GN and the highest overall renewable fraction of 70%. Among the three solar design alternatives, Alternative 3, with the CSP, has the highest capital investment cost with 13% more than Alternative 1-c, with the WECS/PV, yet the LCC of both alternatives were almost the same value indicating the operation cost savings achieved in Alterative 3 versus Alternative 1-c.

The benefits resulting from CER trading as a result of CO_2 emissions indicate a reduction of 7% only in the LCC of Alternative 3 which might not be significant when comparing to the B-a-U case, nevertheless it is an added bonus.

On the other hand, should a feed-in law be introduced soon in the next years with a feed-in tariff of 0.1 €/kWh and at the same present electricity purchase price of 0.035 €/kWh, the LCC of the solar alternatives will reduce; for example, Alternative 3 will have an LCC of 34,084 €/GR which becomes closer to that of the B-a-U.

The results of the REM carried for the different settings of no feed-in law and feed-in law are presented in a portfolio format which enables an overview and forming a quick impression on the economic and environmental performance of the different design alternatives.

Several sensitivity analysis scenarios were carried out on the cost of finance, cost escalation, energy prices and CER prices. The most interesting results are the impact of the energy prices on the LCC. Assuming, the subsidy in the energy prices is removed and the electricity and fuel prices are set at 0.13 €/kWh & 0.5 €/l respectively, the LCC values of the B-a-U versus that of Alternative 3 are: 73,260 versus 51,157 €/GR, respectively. In this case, Alternative 3 with the CSP system would be the most favourable alternative in the view of investors in addition to the environmental advantage.

A breakeven analysis identified that at an electricity purchase price of 0.08 €/kWh and fuel purchase price of 0.3 €/l, the LCC of Alternative 3 breakevens with that of B-a-U case at a value of ca. 47,711 €/GR. This result is important in raising the awareness of need to switch to renewable energy in case of new energy law where subsidies are removed or reduced.

The alternative with the CSP design is further analysed against the B-a-U case where incremental costs in capital investments and operational savings are considered in order to determine the payback period for the RET additional investment. In the case of having a feed-in tariff of 0.1 €/kWh, it was found out the payback period for the additional investment required for Alternative 3 is 18 years with an IRR of 4.2%. Increasing the feed-in tariff to 0.18 €/kWh would reduce the payback period to 10 years, increase the IRR to 14.4% and the profitability index would be above one.

8.4 Conclusion and recommendations

At the beginning of the thesis, the following questions were posed by the author:

1. Can renewable energy cover the energy demand of a five stars resort, located on the Red Sea coast in Egypt?
2. Which environmental technologies are the most suitable in that case?
3. Which is the most economical scenario of renewable energy mix?
4. What are the financial indicators for such scenarios?
5. What is the environmental impact?
6. Can Clean Development Mechanism improve the chances of financial success of such a solution?

The research carried out in this thesis does show that renewable energy can be used to cover the energy demand of a five resort though not 100% but at least more than 30% can be reached depending on the budget available for the project. Wind and solar energy are the most suitable while wind may achieve better performance in some areas other than Sharm el Sheikh such as Marsa Alam and Hurghada where they enjoy higher wind speeds. The author concludes that a mix of wind, PV and thermal collectors or CSP technologies would formulate an optimal solution in economic and environmental terms. However, if compared to the B-a-U case with the prevailing subsidised energy conditions, the solar resort solution is not economical though high reductions in CO_2 could be reached.

It can also be concluded that solar resorts would be an optimal solution for rural areas which are not connected to the national grid such as Marsa Alam. The proposed solar design could still be applied using the proposed combination of renewable energy resources.

It is important to notice that CER revenues alone would not be sufficient to make a non-viable project financially viable. But the CER revenues could turn a marginally viable project into a project with more attractive returns and raise the project in an investor’s ranking of possible investments, thus increasing the likelihood of investment being secured.

It is, therefore, concluded that although solar resorts are technically feasible in Egypt, unfortunately, unless there are significant changes in the energy policy, B-a-U scenarios would continue to prevail the decision making. Nevertheless, the added environmental benefit should not be ignored and investment decisions should start to take a more environmental gain approach rather than financial only.

In order to be able to implement sustainable tourism in Egypt, legislation for touristic developments need to be established where developers would be forced to resorts to RET. As demonstrated, subsidised energy prices and feed/in tariff play a major role in swaying the decision to RET.

The author hopes that the result of this research would be used as an initiator by the tourism and environmental authorities to establish national regulations to limit the energy consumption in hotels and encourage the use of renewable energy. The regulations should aim at reducing the consumption of energy in new and renovated hotels and resorts through the following:

- Establishment of a general framework and common methodology for calculating the integrated energy performance of hotels and resorts.
- The development and application of minimum energy performance standards to new resorts and to certain existing resorts when they are renovated.
- Setting a minimum renewable fraction to new resorts and to certain existing resorts when they are renovated

In addition to legislation, the government needs to provide incentives to investors and developers to encourage them to set environmental sustainability as a criterion in their design brief. As the language of money is a common language used in decisions making, such incentives should instigate financial measures which would improve the life cycle cost of a resort project.

8.5 Future work

The methodology and results presented in this thesis should be used as a basis for further research in the field of energy use in resorts not only in Sharm el Sheikh but also in other similar areas located on the Red Sea in Egypt and neighbouring countries. It was indentified through this thesis the lack of cooperation in providing information by the hotel management in addition to the lack of detailed records about energy consumption.

With the advent of new power law in Egypt, a new form of decision support would be required. There is, hence, a need to undertake a detailed study on resorts with different classifications in the Red Sea region in order to have a better understanding of energy performance in low as well as higher classified resorts. The research should extend to include the breakdown of energy consumptions by installing metering devices in different department in order to gather more accurate information about high consumers. There is also need to research the relationship between building area and energy consumption. The gathered detailed data can be compiled forming a database and a benchmark which can be used by both the authorities to establish best practice and a sanction framework for future sustainable resort developments.

Once, best practice and a database is established, it can be developed with the REM analysis tool into a user-friendly software which can be sued by designers, resort developers & investors and local authorities to evaluate existing and/or future resort developments. The objective is to have a tool that can be used by stakeholders at the early stages of a project when key decisions are made when detailed engineering is not available.

The environmental awareness in the tourism sector in Egypt needs also to be investigated since the audit carried out indicates several misunderstanding and conception about renewable energy technologies. Such a study would identify those misapprehensions and define the remedy methods to improve the chances and acceptance of renewable energy.

Theses on the Dissertation

Problem definition: With the developing countries striving to catch up with those developed, the world's energy demand is projected to significantly increase over the next years resulting in higher global warming and consumption of the limited natural resources. In the meantime, the global contribution from the tourism industry towards energy consumption has steadily increased over the last years. The need for urgent action on the problem of energy security and climate change has now become stronger and convincing, urging the need to use renewable energy technologies and energy efficiency measures in order to achieve energy security and environmental sustainability. Accordingly, the work in this thesis addresses the energy use in the hotel sector in Egypt, one of those developing countries and with a growing tourism industry. The thesis proposes the sola resort concept to decreasing the consumption and dependency on grid power generated by fossil fuels. However, the strong argument by resort developers against solar resorts is the high associated investment costs

Energy in Egypt: Egypt's energy mix is dominated by oil and gas, which is expected to continue so until 2030 accounting for 95% of primary energy demand while its energy demand is projected to grow at an average annual growth rate of 2.6%. Egypt has an extensive system of energy subsidies where energy accounts for the bulk of it. The fact is that electricity price in Egypt is very low representing 14.5% of that in Germany. Although, Egypt stated its intent to increase the share of renewable energy in electricity production, however, the actual share of renewable energy reached 1% only in 2010.

Tourism in Egypt: The tourism industry represents one of the most important features of the national economy formula where it accounts for 23% of the country's foreign currency income. Around 90% of Egypt's tourism investment is now concentrated in the coastal areas of the Red Sea. Egypt embarked on a plan to expand tourism with the aim of increasing the guest room number by at least 71,000 newly constructed rooms in 2017 which is equivalent to around 220 new hotels and resorts.

Aims & objectives: This study investigates the potential of adopting solar resorts in Egypt. The technical feasibility is verified in terms of renewable energy covering the energy demand of a five star resort, located on the Red Sea coast in Egypt. Various configurations of the energy production system for a solar resort are examined. The objective of this thesis is to evaluate the economic and environmental performance of solar resorts using renewable energy technologies versus the conventional resort defined as the business-as-usual (B-a-U) case. A resort evaluation model (REM) is developed using the concept of environmental life cycle costing to determine the life cycle cost and CO_2 emissions of a resort. The model identifies the gaps and breakeven values between the B-a-U case under the prevailing energy structure and the what-if scenarios of introducing a feed-in law or increasing the energy prices in Egypt.

Energy use in hotels: The literature review carried out shows the lack of studies and information regarding energy use in hotels and use of renewable energy in small to medium scale applications in Egypt. Meanwhile, very few studies were carried out worldwide investigating the energy use in hotels and only one benchmark was identified reflecting the global trend in energy and water consumption. The energy use intensity varies from one study to the other such as consumption per sq. meter, guest room or guest-night making it difficult to compare the results of all studies. All studies concur on the high electrical consumption of HVAC systems ranging between 45 to 63% of the total power consumption of a resort.

Use of renewable energy technologies (RET) in hotels: Most of the literature and published case studies on renewable energy and sustainability in the hotel sector deal with small capacities having less than 100 beds. The literature indicates that the most widespread and successful RET is solar thermal collectors used for heating and hot water production. Very few cases illustrate the use of PV and WECS. Most of the published studies lack adequate information about the return on investment or other critical economical indicators which can allow rigorous comparison of renewable energy options. Generally, it is observed that supported by a backup system, RET can be successfully technically applied, yet remains the question whether all of those case studies represent the reality from the economic point of view.

Definition of case study: As a result of the lack of information regarding energy use in the hotel sector in Egypt, a survey is carried out on the five stars resorts in Sharm el Sheikh. Being one of the newly developed and most successful resort destinations on the Red Sea coast, Sharm el Sheikh is chosen as the case study for investigating the energy performance of resorts. The investigation is limited to resorts classified as five stars due to their high consumption rates associated with their high standards, spacious areas and multiple facilities.

Survey: The survey shows that Sharm el Sheikh contains 126 resorts, of which 29% are classified as five stars while 30% as four stars. This indicates that 59% of the resorts are built with high standards and various facilities requiring high demands of energy. The survey also shows that ca. 78% of the five stars resorts have an accommodation capacity ranging from 200 to 500 guest rooms.

Energy audit: The questionnaire followed by a walk-through audit shows that only 39% of the five stars resorts responded while 19% only supplied consistent and usable data. This indicated a great reluctance of supplying information as well as lack of recorded information. Only 28% of the seven audited resorts recorded their consumptions from the first day of operation while the rest started recording one or two years later.

Design practices: The survey shows that the architect is usually under pressure from the owner to maximize the number of guest rooms in order to increase the return of investment. The types of materials chosen are the same used in any other commercial and residential building. Almost none of the audited resorts applied building energy efficiency measures where 0% did not use any thermal insulation in their walls and only one resort (14%) used double glazing in their window façades. All audited resorts depend on grid supplied power while 85% used fuel operated boilers to cover their thermal energy needs and only one resort used solar collectors. All audited resorts used electrically operated air conditioning systems and 43% of the audited resorts used water saving measures.

Occupancy: The monthly guest numbers show that all resorts are non-seasonal and operate all year round. The average guest to room ratio of the audited resorts is 1.89 while the average yearly room occupancy lies between 70% and 90%.

Electricity consumption: The analysed data for electricity consumption of the audited resorts indicate electricity consumption ranging from 38 to 58 kWh per guest-night. Comparing those figures to those mentioned in the other studies, it is deduced that electricity consumption in Sharm el Sheikh is comparable to Europe and New Zealand while almost double that of Cyprus and triple that of Majorca. The monthly consumption rates indicate a steady consumption throughout the year except for the summer months of July and August where an increase of ca. 25% occurs.

Fuel consumption: The average fuel consumption lies between 1.5 & 3 litres of diesel per guest-night. The monthly consumption rates indicate a decrease by ca. 30% during summer periods from May to October which is attributed to the lower need for water heating during the summer time.

Water consumption: The water consumption per guest-night varies between 0.6 and 1 cubic meter. The benchmark values in tropical regions show that consumption less than 0.9 m^3/GN is excellent while consumption between 0.6 to 0.75 m^3/GN in Mediterranean regions is considered satisfactory. It is noted that 85% of the audited resorts showed a steady consumption rate throughout the year.

Occupancy versus consumption: the audited resorts show that guest night consumption does not vary greatly when occupancy is above 70% while it increases tremendously once the occupancy starts to drop below 70%. This indicates the significance of considering occupancy during energy use evaluations.

Overall consumption costs: The total cost of energy consumption for power, fuel and LPG varies from 1.17 to 1.85 €/GN based on the Egyptian prices of energy: 0.029 €/kWh, 0.133 €/kg, 0.067 €/litre for electricity, LPG and fuel respectively at Sharm el Sheikh and an exchange rate of 1 Euro = 7.5 EGP. Six out of the seven audited resorts show an electricity share of 85% to 90% of the total energy consumption costs while a fuel share of 10% to 12%. Only three resorts used LPG with a share of 1% to 3% on the total consumption costs.

Design electricity demand versus actual consumption: The design value of the total daily power demand, 30.6 MW, is compared to the actual consumption of the B-a-U case: Resort 6. In the year 2006 and at an average occupancy of 89%, the average daily consumptions in the months of August & September were 29.25 & 26.071 MWh respectively indicating that the design values are reliable to use, resembling the reality.

High power consumers in the B-a-U case: The breakdown of the design energy demand shows that the air conditioning, RO desalination plant and kitchen equipment are the highest consumers having a share of 59%, 4% and 5% of the design peak load while having a share of 61%, 9% and 7% of the design daily consumption respectively.

Design fuel demand versus actual consumption: The actual fuel consumption of the B-a-U-case is lower than the estimated design value by ca. 20%. However, considering the median value of the actual guest-night consumption for the audited resorts, the design value is lower by 8% only. This signifies the presence of overestimation and the potential to reduce the capacity and size of the thermal energy production system.

High fuel consumers in the B-a-U case: It is observed that the thermal energy produced by the boiler is almost distributed evenly among the three main consumers: Domestic hot water, swimming pool heating and laundry, with a share of 42.5%, 30% and 27.5% respectively.

CO_2 emissions in the B-a-U case: The CO_2 emissions produced in the B-a-U case is estimated to be 35.35 kgCO_2 equiv./GN. Assuming a guest to room ratio of 1.85 and 100% occupancy, the annual generation of CO_2 is ca. 23.6 tonnes per guest room which is more than double that mentioned in the few published studies.

Distribution of operation cost and CO_2 emissions: The breakdown figures of the B-a-U case indicate that electricity is the main contributor in operation costs and generated CO_2 emissions reaching 85% and 80% respectively while fuel has a share of 13% and 18% respectively. LPG has a minor impact on operation costs and emissions with a share of 2% only.

Design capacity versus actual consumption for fresh water: The design capacity for the desalination plant reflects the real consumption where the actual consumption is ca. 92.4% of the production capacity of the desalination plant.

Types of usable renewable energy: Investigating the actual data of the different types of renewable energy, it is to be noted that both solar and wind energy are the most appropriate to be used in small to medium applications like resorts in the Red Sea region. However, wind is more advantageous along the south east coast where it enjoys high wind speeds such as Hurghada and Marsa Alam.

The solar resort design alternative with combined wind energy conversion & photovoltaic systems: The amount of power produced by the wind and solar energy mix is around 42% of the total electricity demand while 58% is to be supplied through the grid system. An excessive amount of ca. 9% is available for selling during the non-peak hours.

The solar resort design alternative with combined wind energy conversion & photovoltaic systems and solar collectors: Similar to the previous alternative with the addition of the solar collectors supplying up to 26% of the thermal energy demand while 74% is covered though fuel operated boilers.

The solar resort design alternative with combined cogeneration concentrated solar power and photovoltaic systems: The amount of power produced by solar energy is around 67% of the total electricity demand while 33% is to be supplied through the grid system. An excessive amount of ca. 10% is available for selling during the non-peak hours. The rejected heat from the CSP system is used in supplying 94% of the thermal energy demand while the remaining 6% is supplied by fuel operated boiler. Using solar cooling system for air conditioning resulted in reducing the power demand by 46% from that of the B-a-U case.

Total calorific value of non-renewable energy sources: Based on using renewable energy for at least 42% of the electricity demand and 26% of the thermal energy demand, the non-renewable energy consumption is reduced by 44% with respect to the B-a-U case.

Renewable fraction: The overall renewable fraction calculated on the basis of cost savings resulting from using renewable energy is 30%, 35% and 70% for the alternatives with wind & PV mix, wind, PV & solar collector, and CSP & PV respectively. The alternative with CSP & PV shows the highest renewable fractions for electricity and thermal energy: 64% and 86% respectively.

Environmental performance of solar resort: The resort evaluation model shows that CO_2 emissions decreases by 44%, 57% & 80% for the solar resort with wind & PV mix, wind, PV & solar collector, and CSP & PV respectively. The less the resort is dependent on grid supplied power, the more the reduction in CO_2 is.

Total capital investment of solar resorts: The total capital investment increases tremendously with the increase of renewable fraction reaching 385% of the capital investment in the B-a-U case.

Annual operation cost of solar resorts: The annual operation cost resulting from the purchase of grid electricity and fuel decreases gradually with the increase in renewable fraction reaching 44% of that of the B-u-U case.

Life cycle cost of solar resorts: Under the current conditions in Egypt where no feed-in law is implemented and with the greatly subsidised energy prices, the LCC of all solar resort alternatives exceed that of the B-a-U case by an average of 49%. The LCC of the three solar alternatives lies within the same range.

Impact of CER benefits on results: The added benefits resulting from trading the CER at a price of 16 €/tCO_2 results in a slightly lower LCC of the solar alternatives but still remains above that of the B-a-U by 41%. The risk of a different CER price is low where an increase or decrease in the CER price by 50% results in the change of the LCC by an average plus or minus 3% respectively.

Impact of feed-in law on results: Introducing a feed-in tariff of 0.10 €/kWh and keeping the existing purchasing price of 0.035€/kWh, improves the LCC of the solar alternatives greatly yet remains higher by 17% with respect to the B-a-U.

Impact of cost of Finance on results: The sensitivity analysis carried out on the equity ratio and cost of debt shows that those two parameters have a minor impact on the results and, eventually, the decision. The average LCC of the solar alternatives still remains almost the double of that of the B-a-U case.

Impact of cost of escalation on results: It is observed that the higher the renewable fraction is, the lower the impact of cost escalation on the LCC is, due to the lower dependency on fossil fuels.

Impact of energy prices on results: This is the most critical factor in the model’s formula with the highest impact on the evaluation results. In the case of major increase in the energy prices or removal of subsidies, the LCC of the B-a-U case increases greatly while that of solar alternatives decreases. At a purchase price of 0.13 €/kWh and 0,5 €/litre for electricity and fuel respectively, the average LCC of the three solar alternatives is 20% less than that of the B-a-U case.

Breakeven values: The study shows the LCC the B-a-U case where no efficiency measures nor renewable energy are used would start to breakeven with the alternative with CSP & PV at an electricity purchase price of 0.08 €/kWh and a fuel purchase price 0.3 €/litre. Meanwhile, the alternative with wind, PV & solar collector would breakeven with the B-a-U at a higher fuel price of 0.5 €/l. The solar alternative with wind & PV has a breakeven point at an electricity price of 0.13 €/kWh and the existing fuel price of 0.11 €/l.

Payback period of solar resort: Evaluating the solar alternative with CSP & PV against the B-a-U case in terms of its payback period, profitability index and internal rate of return, the results show that starting from a feed-in tariff rate of 0.2 €/kWh and at the current purchase price of 0.035 €/kWh, the projects starts to be profitable with respect to the additional investment made to the B-a-U yielding a payback period of 10 years, profitability index of 1.28 and an internal rate of return 14.4%.

Impact of having a grant on the results: A funding grant of 30% with a lower feed-in tariff at 0.10 €/kWh results in a payback period of 13 years, an internal rate of return of 8.8% and a profitability index less than one.

Overall result: There is an obvious environmental benefit by adopting solar resort concept, yet there is a need to introduce new legislations and change the existing energy law in Egypt to encourage resort developers to switch to renewable energy.

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Appendices

Appendix 1: Energy Audit Questionnaire

Appendix 2: Design electricity demand for Resort 6, B-a-U- case

Appendix 3: REM inputs, outputs and sensitivity analyses

Appendix 1

PART 1: Investment Costs

1. Background Information:

1.1. Name of Resort:	
1.2. Location:	Town/City:
1.3. Resort grade (stars):	
1.4. Management Company:	
1.5. Total Resort area:	m^2
1.5.1. Total area of built land	m^2
1.5.2. Total area of Landscape	m^2

2. Design Information:

2.1. Number of guest rooms:						
2.2. Guest room average area:	m^2					
2.3. Number of buildings containing the rooms distributed:						
2.4. Type and number of rooms (chalets, blocks, building, etc.)						
2.4.1 Chalets type:	Quantity					GR
2.4.2 Blocks type:	No of blocks:		Total number of rooms in blocks:			GR
2.4.3 Building:	No of floors		Total number of rooms:			GR
2.5. Swimming Pools:						
2.5.1 Swimming pool 1:	Area, m^2:		Heated:	Yes / No	Volume, m3:	
2.5.2 Swimming pool 2:	Area, m^2:		Heated:	Yes / No	Volume, m3:	
2.5.3 Swimming pool 3:	Area, m^2:		Heated:	Yes / No	Volume, m3:	
2.5.4 Swimming pool 4:	Area, m^2:		Heated:	Yes / No	Volume, m3:	
2.5.5 Swimming pool 5:	Area, m^2:		Heated:	Yes / No	Volume, m3:	
2.6. Number of outlets (restaurants, bars, café, etc…):						
2.7. Area of Kitchen, m^2:						
2.8. Area of Laundry, m^2:						

3. Building/Construction Costs:

3.1. Type of foundation:		
Quantity:	m^3	Foundation Cost:
3.2. Type of superstructure:		
Quantity:	m^3	Superstructure Cost:

3.3. Type of exterior walls:	Brick type:		Double / Single
Quantity:	m^2	Exterior walls Cost:	
3.4. Type of interior walls:			
Quantity:	m^2	Interior walls Cost:	
3.5. Type of walls thermal insulation:		Thickness cm:	
Quantity:	m^2	Thermal insulation Cost:	
3.6. Type of roof thermal insulation:		Thickness cm:	
Quantity:	m^2	Thermal insulation Cost:	
3.7. Type of window glazing:	Double / single / tinted / reflecting	Thickness cm:	
Quantity:	m^2	Windows Cost:	
3.8. Type of ext. glass doors:	Double / single / tinted / reflecting	Thickness cm:	
Quantity:	m^2	Ext. glass doors Cost:	
3.9. Type of walls finishing (inside):			
Quantity:	m^2	Walls finishing Cost:	
3.10. Type of walls finishing (exterior):			
Quantity:	m^2	Walls finishing Cost:	

4. Electrical Works Costs:

4.1. Total electrical load:	MW		
4.2. Source of electricity:	Grid/ Generator/ Photovoltaic/ …….., etc.		
4.2.1. Transformers	Quantity:	Capacity: MW	Cost/transformer:
4.2.2. Main Generator	Quantity:	Capacity, MW:	Cost/generator:
4.2.3. Emergency Generator	Quantity:	Capacity, MW:	Cost/generator:
4.2.4. Photovoltaic	Area, m^2:	Capacity, MW:	Cost:
4.2.5. Other power sources:			
4.3. Ext. Network cabling:	Quantity, m	Total Cost	
4.4. Int. Network cabling:	Quantity, m	Total Cost	
4.5. Control Panels:		Total Cost	

4.6. Guest room power savers:	Quantity:	Total Cost	
4.7. Lighting:	Type of lightings:		
		Total Cost of lighting	
4.8. Public areas light sensors:	Quantity	Total Cost	
4.9. Average estimated lighting electricity consumption/year		kWh	
4.10. Average estimated fuel consumption/year (in case of off-grid resorts)		Litre	
4.11. Average estimated total electricity consumption of resort/year		kWh	

5. HVAC Information:

5.1. Total air volume: m^3		
5.2 Types of air conditioning used:	Central / split units/ DX units / ………./ ……….. /……………….	
5.3. Central A/C:	Type of chillers: Air cooled/ water-cooled/ absorption chillers	
5.3.1 Number of units:	Capacity: TR BTU	
5.3.2. Air volume served by Central A/C, m^3:		
5.3.3. Areas served by Central A/C:	public areas/no. of guest rooms ……/ …………/…………	
5.3.4. Total cost of central A/C including AHU, FCU, fans, piping, ducts, etc...:		
5.4. Split units A/C:	Quantity of units:	Average capacity: BTU HP
5.4.1 Areas served by split:	public areas / no. of guest rooms ……../ ………./……………	
5.4.2. Total cost of split A/C including piping, ducts, etc...:		
5.5. Average estimated A/C electricity consumption/year	kWh	
5.6. Source of hot water supply:	Boilers / solar heaters/ electrical heaters / ………. / ………….	
5.7. Amount of hot water required:	Amount of steam required:	
5.8. Boilers:	Type: hot water / steam / ………. /	
5.8.1. No of operating units:	Capacity:	
5.8.2. Number of guest rooms served by boilers:		

5.8.3. Fuel type of boiler:	
5.8.4. Total cost of all installation inside boiler room:	
5.8.5. Average estimated fuel consumption/year:	
5.9. Solar heaters:	Type:
5.9.1. Unit capacity:	No of units:
5.9.2. Number of guest rooms served by solar heaters:	
5.9.3. Total cost of solar heaters:	
5.9.4. Average estimated electricity consumption/year:	
5.10. Electrical heaters: Unit capacity:	No of units:
5.10.1 Number of guest rooms served by electrical heaters:	
5.10.2. Total cost of electrical heaters:	
5.10.3. Average estimated electricity consumption/year:	

6. Rooms electrical contents:

6.1. Guest room electrical load:	Watt

7. Kitchen:

7.1. Electrical equipment, kW:
7.2. Gas equipment, kW:
7.3. Cooling Rooms, kW:
7.4. Average estimated kitchen electricity consumption/year, kWh:
7.5. Average estimated kitchen gas consumption/year, ton:

8. Waste water treatment station:

8.1. Capacity, m^3/day:
8.2. Type of treatment:

8.3. Cost of station:
8.4. Average estimated electricity consumption/year, kWh:

9. Desalination station:

9.1. Capacity, m^3/day:
9.2. Type of treatment:
9.3. Cost of station: installations:
9.4. Average estimated electricity consumption/year, kWh:

PART 2: Operation and Maintenance Costs

10.1. Monthly Water consumption, m^3:		
10.2. Monthly electricity consumption, kWh:		
10.3. Monthly fuel consumption, Liter:		
10.4. Monthly gas consumption, Ton:		
10.5. Parts replacement:		
10.5.1 Estimated cost of HVAC parts replacement:	After 5 years	
	After 10 years	
	After 15 years	
	After 20 years	
	After 25 years	
Expected complete HVAC system replacement	Number of years:	Cost:
10.5.2 Estimated cost of Boilers parts replacement:	After 5 years	
	After 10 years	
	After 15 years	
	After 20 years	
	After 25 years	
Expected complete Boilers system replacement	Number of years:	Cost:

10.5.3 Estimated cost of electrical heaters parts replacement:	After 5 years	
	After 10 years	
	After 15 years	
	After 20 years	
	After 25 years	
Expected complete electrical heaters system replacement	Number of years:	Cost:
10.5.4 Estimated cost of solar heaters parts replacement:	After 5 years	
	After 10 years	
	After 15 years	
	After 20 years	
	After 25 years	
Expected complete solar heaters system replacement	Number of years:	Cost:
10.5.5 Estimated cost of waste water treatment parts replacement:	After 5 years	
	After 10 years	
	After 15 years	
	After 20 years	
	After 25 years	
Expected complete waster water treatment system replacement	Number of years:	Cost:
10.5.6 Estimated cost of desalination station parts replacement:	After 5 years	
	After 10 years	
	After 15 years	
	After 20 years	
	After 25 years	
Expected complete desalination station replacement	Number of years:	Cost:

Appendix 2

Buisness-as-Usual Case

ELECTRIC CONSUMPTION

ITEM	BUILDING	UTILITY DESCRIPTION	Running Time hrs/day	ELEC. POWER kW	Energy kWh
A	HOTEL A				
A-1	Air Condition - 2x90 tons + 143 FCU + 17 AHU		16	606,528	9704,448
A-2	Reception				
A-2.01		Lighting	8	2,4	19,2
A-2.02		Computers	8	15	120
A-2.03		TV Sets	2	26	52
A-2.04		Sound System	15	3	45
A-2.05		Telephone & monitoting System	24	0,8	19,2
A-3	House Keeping				
A-3.01		Equipment	6	14,7	88,2
A-3.02					
A-4	Admin Offices & BOH				
A-4.01		Equipment	12	3	36
A-4.02		Computers	incl.		
A-4.03		Lighting	12	1	12
A-5	Ex- Lobby Bar				
A-5.01		Beverage Equipment	24	0,42	10,08
A-5.02		Lighting	6	0,3	1,8
A-5.03					
A-6	Latitude Bar				
A-6.01		Beverage/Kitchen Equipment	24	0,42	10,08
A-6.02		Lighting	6	0,3	1,8
A-6.03		Other Equipmet			
A-7	Guestrooms (130)				
A-7.01		Lighting	1,5	33,8	50,7
A-7.02		Air Condition	incl		
A-7.03		TV Sets	incl		
		Mini Bar	24	2,4375	58,5
B	ANNEX A				
B-1	Air Condition - 2*190 tons + 6 AHU + 33 FCU + 3 pumps		12	547,776	6573,312
B-2	Ball Room				
B-2.01		Lighting	2	2	4
B-2.02		Audio/Video Equipment	2	2	4
B-2.03		Banquet Area			
B-2.04		Other Equipment			
B-3	14 Shops				
B-3.01		A/C Fan Coils	12	2,8	33,6
B-3.02		Lighting	12	5,6	67,2
B-3.03		Special Equipment	12	4,2	50,4
B-4	Cinemas				
B-4.01		Equipment	4	6	24
B-4.02		Air Condition - 3 AHU	4	1,5	6
B-4.03		Lighting	4	0,4	1,6
B-5	Night Club				
B-5.01		Beverage Equipment	24	0,42	10,08
B-5.02		Lighting	6	0,3	1,8
B-5.03		Sound & Light Equipment	8	10	80
B-5.04		Other Eqpuipment			
B-6	Western Pub				
B-6.01		Beverage/Kitchen Equipment	24	0,42	10,08
B-6.02		Lighting	6	0,3	1,8
B-6.03		Other Equipmet			

B-7	Video Corner				
B-6.01		A/C Fan Coils	8	0,2	1,6
B-6.02		Lighting	8	0,4	3,2
B-6.03		Special Equipment	8	0,3	2,4
C	ANNEX B				
C-1	Air Condition		incl.		
C-2	Kitchen				
C-2.01		Equipment	8,00	182	1456
C-2.02		Lighting	14	3	42
C-3	Restaurants				
C-3.01		Lighting	4	6	24
C-3.02		Sound System	10	0,4	4
C-3.03		Buffet Equipmet	4	15	60
C-3.04		Hot Counter Equipmet	10	1,25	12,5
C-4	Laundry				
C-4.01		Equipment	4	80	320
C-4.02		Lighting	16	2,25	36
C-5	Cold Rooms - 5 for storage		16	10,5	168
C-6	SP A & C Pump Rooms		24	19,5	468
	SP A lightning		8	6,6	52,8
	SP A waterfall		16	0,75	12
C-7	3 Fountains/water curt		14	9	126
C-8	Admin Offices	Lighting + Equipment	12	1	12
D	SP B Pump Rooms		24	11	264
	SP B Lighting		8	4,2	33,6
E	Floating Cafeteria				
		Cafeteria Equipment	24	0,42	10,08
		Lighting	6	0,3	1,8
F	Chalets & Studios				
		Lighting	1,5	42,12	63,18
		Air Condition	8	243	1944
		TV Sets	2	18	36
		Mini Bar	24	1,69	40,5
G	Staff Building	Lighting	1,5	7,56	11,34
		Air Condition	10	67,5	675
		TV Sets	2	4,2	8,4
		Mini Bar	24	0,39375	9,45
H	Other				
H-1	Fountains pumps		15	30	450
	Fountains lights		8	2,15	17,2
H-2	Desalination Plant		24	115	2760
H-3	Sewage Treatment Plant		16	30	480
H-4	Gym		12	7,42	89,04
	Health club		6	14	84
H-5	Boilers		16	24,36	389,76
H-6	Booster Pumps		3	37,3	111,9
H-7	Landscape lights		8	333	2664
H-8	Elevators		6	6	36
			*****************	*****************	**************
		TOTAL POWER CONS. -----------------		2,632	30,60
				MW	MWh
			***************	***************	******************

REM inputs, outputs and sensitivity analysis

TECHNICAL INPUT SHEET

blue boxes with yellow text are for Data Input
text in blue are calculated

Project Name:			Scenario:		
Resort Design			Business-as-Usual Case		
Location:			Number of Guest Rooms:		
Sharm El Sheikh			344		
	Energy Consumption			**Energy Production**	
C1	Average Annual Occupancy	100%	ER1	Annual Amount of produced electricity by RET, kWh	-
C2	Average no. of occupied rooms per year	125.560	ER2	Average produced RET electricity, kWh / GN	-
C3	Guest to Room Ratio	1,85	ER3	Annual Amount of produced electricity by non-RET, kWh	11.172.957
C4	Average no. Of guest-nights, GN, per year	232.286	ER4	Average produced non-RET electricity, kWh / GN	48,10
C5	Average Electricity consumption / GN, kWh	48,10	ER5	Annual Amount of produced thermal energy by RET, kWh	
C6	Annual Electricity consumption, kWh	11.172.957	ER6	Average produced RET thermal energy, kWh / GN	-
C7	Average Fuel consumption / GN, l	2,43	ER7	Annual Amount of produced thermal energy by non-RET, kWh	5.131.409
C8	Annual Fuel consumption, l	564.455	ER8	Average produced non-RET thermal energy, kWh / GN	22,09
C9	Average Thermal Energy consumption / GN, kWh	22,09		**CO2 Emissions**	
C10	Annual Thermal Energy consumption, kWh	5.131.409	CE1	CO2 conversion factor 1 MWh Grid Electricity : 1 ton Co2	0,59
	Energy Demand		CE2	CO2 conversion factor 1 litre Diesel fuel : 1 ton Co2	2,63
DD1	Surplus in supply, kWh / year	-	CE3	Annual amount of equivalent CO2 emissions	8.077
			CE4	Average amount of equivalent kg CO2 / GN	34,77

ECONOMICAL INPUT SHEET

blue boxes with yellow text are for Data Input
text in blue are calculated

Project Name:	Scenario:
Resort Design	Business-as-Usual Case
Location:	Number of Guest Rooms:
Sharm El Sheikh	344

Financial Parameters

FP1	Equity ratio, ER	30%
FP2	Fund Grant	0%
FP3	Debt ratio, DR	70%
FP4	Cost of finance, Rd	5,50%
FP5	Expected return on equity, Re	15,00%
FP6	Term of loan in years, ToL	10
FP7	Term of Grant in years, ToG	0
FP8	Equity by Owner, E	1.015.657 €
FP9	Grant amount	- €
FP10	Debt to Bank, D	2.369.867 €
FP11	Weighted Average Cost of Capital, WACC	8,35%
FP12	Feed-in Tariff fixed rate per kWh	0,035 €
FP13	Feed-in Tariff added premium per kWh	- €
FP14	Feed-in Tariff added premium term in years	0
FP15	CER price per ton CO2	- €
FP16	CER term in years	0
FP17	Cost Escalation factor	2,0%
FP18	Change in feed-in Tariff	0,0%
FP19	Change in CER prices	0,0%

Project Parameters

PP1	Total Capital Investment, TCI	3.385.524,00 €
PP2	Project Life time in years	25
	ANNUAL COSTS:	
PP3	M & R Cost as % of TCI	2,0%
PP4	Annual M&R Cost, AMRC	67.710 €
PP5	Electricity purchase price per kWh	0,035 €
PP6	Fuel purchase price per litre	0,11 €
PP7	Annual Electricity Operational Costs	391.053 €
PP8	Annual Fuel Operational Cost	62.090 €
	ANNUAL REVENUES & BENEFIT	
PP9	Annual Revenue from selling electricity fixed	- €
PP10	Annual Revenue from selling electricity add-on	- €
PP11	Annual Revenue from CER	- €
	Salvage Cost	
PP12	Salvage Cost as % of TCI	5,0%
PP13	Total salvage Cost, TSC	169.276 €

REM OUTPUT SHEET

Project Name:			Scenario:		
Resort Design			Business-as-Usual Case		
Location:			Number of Guest Rooms:		
Sharm El Sheikh			344		

Economical parameters

Before Debt & Grant	per GR	Total	Including Debt & Grant	per GR	Total
LCC before Debt	28.351 €	9.752.879 €	LCC after D & G	27.553 €	9.478.300 €
NPV of Cash Flow before Debt	- 28.351 €	- 9.752.879 €	NPV of Cash Flow After D & G	- 27.553 €	- 9.478.300 €

Environmental parameters

Average equivelant CO2 emissions	kg per GN	tonnes/Annual
	34,77	8.076,56

ECONOMICAL ANALYSIS SHEET

blue boxes with yellow text are for Data Input
text in blue are calcultated

Project Name:	Scenario:
Resort Design	Business-as-Usual Case
Location	Number of Guest Rooms:
Sharm El Sheikh	344

Project Life 25

		Totals	0	1	2	3	4	5	6	7	8	9	10
Net Capital Costs													
Capital Project Name	€	(3.385.524,00)	(3.385.524,00)	-	-	-	-	-	-	-	-	-	-
Total Capital Investment	€	**(3.385.524,00)**	**(3.385.524,00)**	-	-	-	-	-	-	-	-	-	-
Operating and Maintenance Costs													
Maintenance Costs	€	(1.692.762,00)	-	(67.710,48)	(67.710,48)	(67.710,48)	(67.710,48)	(67.710,48)	(67.710,48)	(67.710,48)	(67.710,48)	(67.710,48)	(67.710,48)
Electricity Costs	€	(9.776.337,03)	-	(391.053,48)	(391.053,48)	(391.053,48)	(391.053,48)	(391.053,48)	(391.053,48)	(391.053,48)	(391.053,48)	(391.053,48)	(391.053,48)
Fuel Costs	€	(1.552.251,20)	-	(62.090,05)	(62.090,05)	(62.090,05)	(62.090,05)	(62.090,05)	(62.090,05)	(62.090,05)	(62.090,05)	(62.090,05)	(62.090,05)
Total O&M Costs excl. Escalation	€	**(13.021.350,22)**	-	**(520.854,01)**	**(520.854,01)**	**(520.854,01)**	**(520.854,01)**	**(520.854,01)**	**(520.854,01)**	**(520.854,01)**	**(520.854,01)**	**(520.854,01)**	**(520.854,01)**
Price Escalation Costs													
Price escalation				100%	102%	104%	106%	108%	110%	113%	115%	117%	120%
Escalation of Costs	€	(3.661.759,79)	-	-	(10.417,08)	(21.042,50)	(31.880,43)	(42.935,12)	(54.210,90)	(65.712,20)	(77.443,53)	(89.409,48)	(101.614,75)
Total O&M Costs incl. Escalation	€	**(16.683.110,01)**	-	**(520.854,01)**	**(531.271,09)**	**(541.896,51)**	**(552.734,44)**	**(563.789,13)**	**(575.064,91)**	**(586.566,21)**	**(598.297,53)**	**(610.263,49)**	**(622.468,76)**
Revenue and Operating Benefits													
Revenue from selling electricity fixed	€	-	-	-	-	-	-	-	-	-	-	-	-
Revenue from selling electricity add on			-	-	-	-	-	-	-	-	-	-	-
Benefit from CER	€	-	-	-	-	-	-	-	-	-	-	-	-
Total Benefits and Revenue	€	-	-	-	-	-	-	-	-	-	-	-	-
Price Escalation of Revenues													
Price change of Feed-in Tarrif fixed part				100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Escalation/decrease in Revenue	€	-	-	-	-	-	-	-	-	-	-	-	-
Price change in CER				100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Escalation/decrease in Benefits	€	-	-	-	-	-	-	-	-	-	-	-	-
Total R&B Costs incl. Escalation	€	-	-	-	-	-	-	-	-	-	-	-	-
Total Salvage Cost	€	**169.276,20**	-	-	-	-	-	-	-	-	-	-	-
EBITDA	€	**(19.899.357,81)**	**(3.385.524,00)**	**(520.854,01)**	**(531.271,09)**	**(541.896,51)**	**(552.734,44)**	**(563.789,13)**	**(575.064,91)**	**(586.566,21)**	**(598.297,53)**	**(610.263,49)**	**(622.468,76)**
Discounted Cash Flow EBITDA	€	**(9.752.879,30)**	**(3.385.524,00)**	**(480.714,36)**	**(452.541,44)**	**(426.019,63)**	**(401.052,16)**	**(377.547,95)**	**(355.421,24)**	**(334.591,29)**	**(314.982,11)**	**(296.522,15)**	**(279.144,07)**
Debt calculation													
Principal Payments	€	(2.369.866,80)		(236.986,68)	(236.986,68)	(236.986,68)	(236.986,68)	(236.986,68)	(236.986,68)	(236.986,68)	(236.986,68)	(236.986,68)	(236.986,68)
Interests	€	(716.884,71)	-	(130.342,67)	(117.308,41)	(104.274,14)	(91.239,87)	(78.205,60)	(65.171,34)	(52.137,07)	(39.102,80)	(26.068,53)	(13.034,27)
Total Debt	€	**(3.086.751,51)**	-	**(367.329,35)**	**(354.295,09)**	**(341.260,82)**	**(328.226,55)**	**(315.192,28)**	**(302.158,02)**	**(289.123,75)**	**(276.089,48)**	**(263.055,21)**	**(250.020,95)**
Net Cash Flow After Debt	€	**(20.616.242,52)**	**(1.015.657,20)**	**(888.183,36)**	**(885.566,18)**	**(883.157,33)**	**(880.960,99)**	**(878.981,41)**	**(877.222,93)**	**(875.689,96)**	**(874.387,02)**	**(873.318,70)**	**(872.489,70)**
Fund Grant													
Grant payments	€	-	-	-	-	-	-	-	-	-	-	-	-
Net Cash Flow After D & G	€	**(20.616.242,52)**	**(1.015.657,20)**	**(888.183,36)**	**(885.566,18)**	**(883.157,33)**	**(880.960,99)**	**(878.981,41)**	**(877.222,93)**	**(875.689,96)**	**(874.387,02)**	**(873.318,70)**	**(872.489,70)**
Discounted Cash Flow after D&G	€	**(9.478.300,33)**	**(1.015.657,20)**	**(819.735,45)**	**(754.333,14)**	**(694.306,66)**	**(639.206,26)**	**(588.620,13)**	**(542.171,25)**	**(499.514,34)**	**(460.333,28)**	**(424.338,58)**	**(391.265,14)**

Life Cycle Cost before Debt	€	9.752.879,30
Life Cycle Cost including D & G	€	9.478.300,33

11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
€ (67.710,48)	€ (67.710,48)	€ (67.710,48)	€ (67.710,48)	€ (67.710,48)	€ (67.710,48)	€ (67.710,48)	€ (67.710,48)	€ (67.710,48)	€ (67.710,48)	€ (67.710,48)	€ (67.710,48)	€ (67.710,48)	€ (67.710,48)	€ (67.710,48)
€ (391.053,48)	€ (391.053,48)	€ (391.053,48)	€ (391.053,48)	€ (391.053,48)	€ (391.053,48)	€ (391.053,48)	€ (391.053,48)	€ (391.053,48)	€ (391.053,48)	€ (391.053,48)	€ (391.053,48)	€ (391.053,48)	€ (391.053,48)	€ (391.053,48)
€ (62.090,05)	€ (62.090,05)	€ (62.090,05)	€ (62.090,05)	€ (62.090,05)	€ (62.090,05)	€ (62.090,05)	€ (62.090,05)	€ (62.090,05)	€ (62.090,05)	€ (62.090,05)	€ (62.090,05)	€ (62.090,05)	€ (62.090,05)	€ (62.090,05)
€ (520.854,01)	**€ (520.854,01)**	**€ (520.854,01)**	**€ (520.854,01)**	**€ (520.854,01)**	**€ (520.854,01)**	**€ (520.854,01)**	**€ (520.854,01)**	**€ (520.854,01)**	**€ (520.854,01)**	**€ (520.854,01)**	**€ (520.854,01)**	**€ (520.854,01)**	**€ (520.854,01)**	**€ (520.854,01)**
122%	124%	127%	129%	132%	135%	137%	140%	143%	146%	149%	152%	155%	158%	161%
€ (114.064,12)	€ (126.762,48)	€ (139.714,81)	€ (152.926,19)	€ (166.401,79)	€ (180.146,91)	€ (194.166,93)	€ (208.467,35)	€ (223.053,77)	€ (237.931,93)	€ (253.107,65)	€ (268.586,88)	€ (284.375,70)	€ (300.480,29)	€ (316.906,98)
€ (634.918,13)	**€ (647.616,49)**	**€ (660.568,82)**	**€ (673.780,20)**	**€ (687.255,80)**	**€ (701.000,92)**	**€ (715.020,94)**	**€ (729.321,36)**	**€ (743.907,78)**	**€ (758.785,94)**	**€ (773.961,66)**	**€ (789.440,89)**	**€ (805.229,71)**	**€ (821.334,30)**	**€ (837.760,99)**
€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -
€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -
€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -
€ -	**€ -**	**€ -**	**€ -**	**€ -**	**€ -**	**€ -**	**€ -**	**€ -**	**€ -**	**€ -**	**€ -**	**€ -**	**€ -**	**€ -**
100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -
100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -
€ -	**€ -**	**€ -**	**€ -**	**€ -**	**€ -**	**€ -**	**€ -**	**€ -**	**€ -**	**€ -**	**€ -**	**€ -**	**€ -**	**€ -**
€ -	**€ -**	**€ -**	**€ -**	**€ -**	**€ -**	**€ -**	**€ -**	**€ -**	**€ -**	**€ -**	**€ -**	**€ -**	**€ -**	**€ 169.276,20**
€ (634.918,13)	**€ (647.616,49)**	**€ (660.568,82)**	**€ (673.780,20)**	**€ (687.255,80)**	**€ (701.000,92)**	**€ (715.020,94)**	**€ (729.321,36)**	**€ (743.907,78)**	**€ (758.785,94)**	**€ (773.961,66)**	**€ (789.440,89)**	**€ (805.229,71)**	**€ (821.334,30)**	**€ (668.484,79)**
€ (262.784,45)	**€ (247.383,60)**	**€ (232.885,35)**	**€ (219.236,79)**	**€ (206.388,11)**	**€ (194.292,46)**	**€ (182.905,68)**	**€ (172.186,24)**	**€ (162.095,03)**	**€ (152.595,23)**	**€ (143.652,18)**	**€ (135.233,25)**	**€ (127.307,72)**	**€ (119.846,67)**	**€ (90.026,14)**
€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -
€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -
€ -	**€ -**	**€ -**	**€ -**	**€ -**	**€ -**	**€ -**	**€ -**	**€ -**	**€ -**	**€ -**	**€ -**	**€ -**	**€ -**	**€ -**
€ (634.918,13)	**€ (647.616,49)**	**€ (660.568,82)**	**€ (673.780,20)**	**€ (687.255,80)**	**€ (701.000,92)**	**€ (715.020,94)**	**€ (729.321,36)**	**€ (743.907,78)**	**€ (758.785,94)**	**€ (773.961,66)**	**€ (789.440,89)**	**€ (805.229,71)**	**€ (821.334,30)**	**€ (668.484,79)**
€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -
€ (634.918,13)	**€ (647.616,49)**	**€ (660.568,82)**	**€ (673.780,20)**	**€ (687.255,80)**	**€ (701.000,92)**	**€ (715.020,94)**	**€ (729.321,36)**	**€ (743.907,78)**	**€ (758.785,94)**	**€ (773.961,66)**	**€ (789.440,89)**	**€ (805.229,71)**	**€ (821.334,30)**	**€ (668.484,79)**
€ (262.784,45)	**€ (247.383,60)**	**€ (232.885,35)**	**€ (219.236,79)**	**€ (206.388,11)**	**€ (194.292,46)**	**€ (182.905,68)**	**€ (172.186,24)**	**€ (162.095,03)**	**€ (152.595,23)**	**€ (143.652,18)**	**€ (135.233,25)**	**€ (127.307,72)**	**€ (119.846,67)**	**€ (90.026,14)**

Business-as-Usual Case

Sensibility's analysis, WACC v. LCC/GN

Equity ratio, ER	Cost of finance, Rd	Weighted Average Cost of Capital, WACC	LCC after D & G / per GR
30%	5,00%	8,00%	28.110 €
30%	6,00%	8,70%	27.025 €
30%	7,00%	9,40%	26.049 €
30%	8,00%	10,10%	25.167 €
40%	5,00%	9,00%	26.359 €
40%	6,00%	9,60%	25.580 €
40%	7,00%	10,20%	24.867 €
40%	8,00%	10,80%	24.214 €
50%	5,00%	10,00%	24.908 €
50%	6,00%	10,50%	24.366 €
50%	7,00%	11,00%	23.862 €
50%	8,00%	11,50%	23.393 €
60%	5,00%	11,00%	23.715 €
60%	6,00%	11,40%	23.353 €
60%	7,00%	11,80%	23.013 €
60%	8,00%	12,20%	22.692 €
70%	5,00%	12,00%	22.743 €
70%	6,00%	12,30%	22.520 €
70%	7,00%	12,60%	22.306 €
70%	8,00%	12,90%	22.101 €
80%	5,00%	13,00%	21.965 €
80%	6,00%	13,20%	21.843 €
80%	7,00%	13,40%	21.724 €
80%	8,00%	13,60%	21.609 €
90%	5,00%	14,00%	21.356 €
90%	6,00%	14,10%	21.306 €
90%	7,00%	14,20%	21.257 €
90%	8,00%	14,30%	21.209 €
100%	5,00%	15,00%	20.893 €
100%	6,00%	15,00%	20.893 €
100%	7,00%	15,00%	20.893 €
100%	8,00%	15,00%	20.893 €

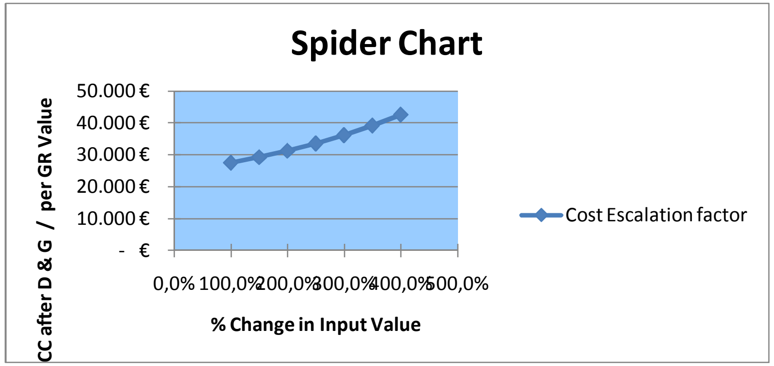
Business-as-Usual Case

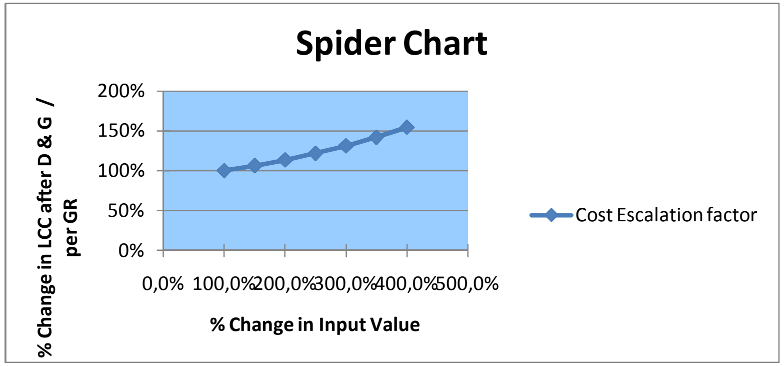
Sensibility's analysis for "LCC after D & G / per GR"

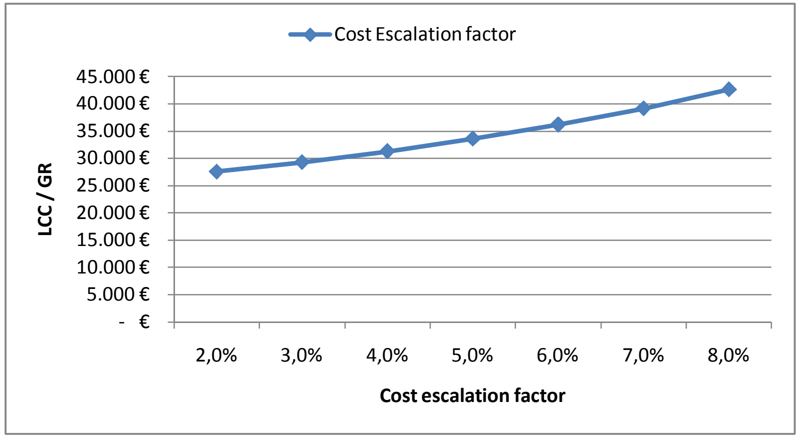
	Input Variables Values						
	100,0%	150,0%	200,0%	250,0%	300,0%	350,0%	400,0%
Cost Escalation factor	2,0%	3,0%	4,0%	5,0%	6,0%	7,0%	8,0%

	Output Variable Values "LCC after D & G / per GR"						
	100,0%	150,0%	200,0%	250,0%	300,0%	350,0%	400,0%
Cost Escalation factor	27.553 €	29.298 €	31.288 €	33.562 €	36.167 €	39.156 €	42.592 €

	Output Variable Percent Variation "LCC after D & G / per GR"						
	100,0%	150,0%	200,0%	250,0%	300,0%	350,0%	400,0%
Cost Escalation factor	100,00%	106,33%	113,56%	121,81%	131,26%	142,11%	154,58%







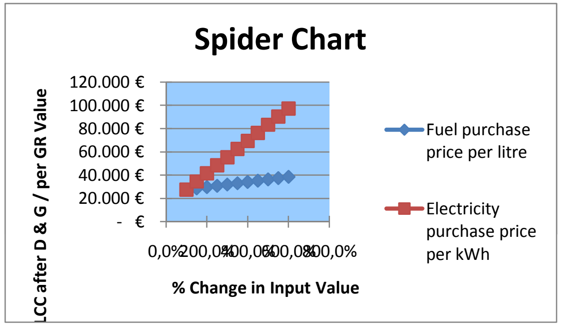
Business-as-Usual Case

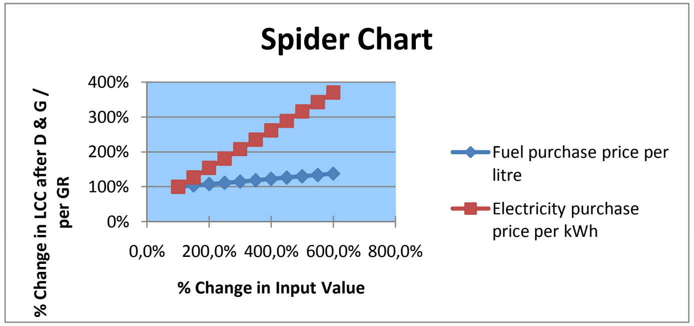
Sensibility's analysis for "LCC after D & G / per GR"

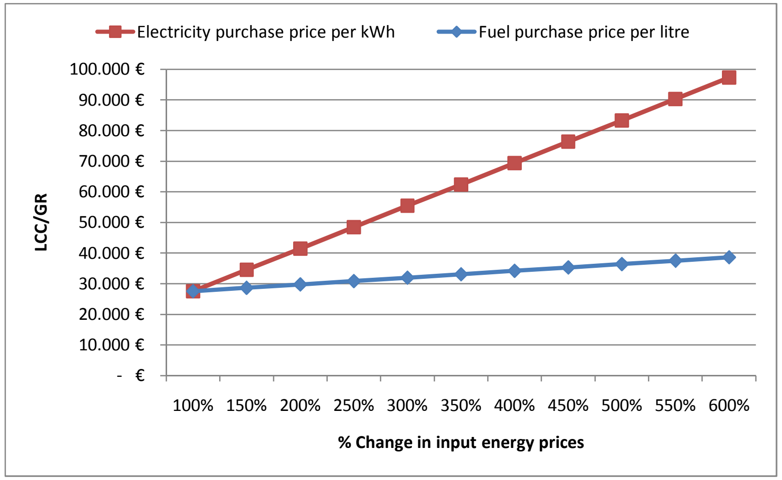
	Input Variables Values										
	100,0%	150,0%	200,0%	250,0%	300,0%	350,0%	400,0%	450,0%	500,0%	550,0%	600,0%
Fuel purchase price p	0,11 €	0,17 €	0,22 €	0,28 €	0,33 €	0,39 €	0,44 €	0,50 €	0,55 €	0,61 €	0,66 €
Electricity purchase p	0,035 €	0,053 €	0,070 €	0,088 €	0,105 €	0,123 €	0,140 €	0,158 €	0,175 €	0,193 €	0,210 €

	Output Variable Values "LCC after D & G / per GR"										
	100,0%	150,0%	200,0%	250,0%	300,0%	350,0%	400,0%	450,0%	500,0%	550,0%	600,0%
Fuel purchase price p	27.553 €	28.660 €	29.768 €	30.875 €	31.982 €	33.089 €	34.196 €	35.304 €	36.411 €	37.518 €	38.625 €
Electricity purchase p	27.553 €	34.527 €	41.500 €	48.473 €	55.447 €	62.420 €	69.393 €	76.367 €	83.340 €	90.314 €	97.287 €

	Output Variable Percent Variation "LCC after D & G / per GR"										
	100,0%	150,0%	200,0%	250,0%	300,0%	350,0%	400,0%	450,0%	500,0%	550,0%	600,0%
Fuel purchase price p	100,00%	103,75%	107,49%	111,24%	114,99%	118,74%	122,48%	126,23%	129,98%	133,73%	137,47%
Electricity purchase p	100,00%	126,97%	153,95%	180,92%	207,90%	234,87%	261,84%	288,82%	315,79%	342,76%	369,74%







TECHNICAL INPUT SHEET

blue boxes with yellow text are for Data Input
text in blue are calcultated

Project Name:			**Scenario:**		
	Resort Design			**Alternative 1-a (WECS)**	
Location:			**Number of Guest Rooms:**		
	Sharm El Sheikh			**344**	
	Energy Consumption			**Energy Production**	
C1	Average Annual Occupancy	100%	ER1	Annual Amount of produced electricity by RET, kWh	3.552.798
C2	Average no. of occupied rooms per year	125.560	ER2	Average produced RET electricity, kWh / GN	15,29
C3	Guest to Room Ratio	1,85	ER3	Annual Amount of consumed electricity by non-RET, kWh	5.206.975
C4	Average no. Of guest-nights, GN, per year	232.286	ER4	Average produced non-RET electricity, kWh / GN	22,42
C5	Average Electricity consumption / GN, kWh	34,77	ER5	Annual Amount of produced thermal energy by RET, kWh	-
C6	Annual Electricity consumption, kWh	8.077.447	ER6	Average produced RET thermal energy, kWh / GN	-
C7	Average Fuel consumption / GN, l	2,43	ER7	Annual Amount of produced thermal energy by non-RET, kWh	5.131.409
C8	Annual Fuel consumption, l	564.455	ER8	Average produced non-RET thermal energy, kWh / GN	22,09
C9	Average Thermal Energy consumption / GN, kWh	22,09		**CO2 Emissions**	
C10	Annual Thermal Energy consumption, kWh	5.131.409	CE1	CO2 conversion factor 1 MWh Grid Electricity : 1 ton Co2	0,59
	Energy Demand		CE2	CO2 conversion factor 1 litre Diesel fuel : 1 ton Co2	2,63
DD1	Surplus in supply, kWh / year	682.326	CE3	Annual amount of equivelant CO2 emissions	4.557
			CE4	Average amount of equivelant kg CO2 / GN	19,62

ECONOMICAL INPUT SHEET

blue boxes with yellow text are for Data Input
text in blue are calcultated

Project Name:	**Scenario:**
Resort Design	**Alternative 1-a (WECS)**
Location:	**Number of Guest Rooms:**
Sharm El Sheikh	**344**

Financial Parameters

FP1	Equity ratio, ER	30%
FP2	Fund Grant	0%
FP3	Debt ratio, DR	70%
FP4	Cost of finance, Rd	5,50%
FP5	Expected return on equity, Re	15,00%
FP6	Term of loan in years, ToL	10
FP7	Term of Grant in years, ToG	0
FP8	Equity by Owner, E	2.698.124 €
FP9	Grant amount	- €
FP10	Debt to Bank, D	6.295.624 €
FP11	Weighted Average Cost of Capital, WACC	8,35%
FP12	Feed-in Tarrif fixed rate per kWh	0,035 €
FP13	Feed-in Tarif added premium per kWh	- €
FP14	Feed-in Tarrif added premium term in years	0
FP15	CER price per ton CO2	- €
FP16	CER term in years	0
FP17	Cost Escalation factor	2,0%
FP18	Change in feed-in Tarrif	2,0%
FP19	Change in CER prices	0,0%
FP20		

Project Parameters

PP1	Total Capital Investement, TCI	8.993.748 €
PP2	Project Life time in years	25
	ANNUAL COSTS:	
PP3	O & M Cost as % of TCI	2,0%
PP4	Annual O & M Cost, AOMC	179.875 €
PP5	Electricity purchase price per kWh	0,035 €
PP6	Fuel purchase price per litre	0,11 €
PP7	Annual Electricity Operational Costs	282.711 €
PP8	Annual Fuel Operational Cost	62.090 €
	ANNUAL REVENUES & BENEFIT	
PP9	Annual Revenue from selling electricity fixed	124.348 €
PP10	Annual Revenue from selling electricity add-on	- €
PP11	Annual Revenue from CER	- €
	Salvage Cost	
PP12	Salvage Cost as % of TCI	5,0%
PP13	Total salvage Cost, TSC	449.687 €

REM OUTPUT SHEET

Project Name:	Scenario:
Resort Design	Alternative 1-a (WECS)
Location:	**Number of Guest Rooms:**
Sharm El Sheikh	344

Economical parameters

Before Debt & Grant	per GR	Total	Including Debt & Grant	per GR	Total
LCC before Debt	40.246 €	13.844.650 €	LCC after D & G	38.126 €	13.115.223 €
NPV of Cash Flow before Debt	- 40.246 €	- 13.844.650 €	NPV of Cash Flow After D & G	- 38.126 €	- 13.115.223 €

Environmental parameters

	kg per GN	tonnes / year
Average equivelant CO2 emissions	19,62	4.557

ECONOMICAL ANALYSIS SHEET

blue boxes with yellow text are for Data Input
text in blue are calcultated

Project Name:	Scenario:
Resort Design	Alternative 1-a (WECS)
Location	Number of Guest Rooms:
Sharm El Sheikh	344

Project Life	25

		Totals	0	1	2	3	4	5	6	7	8	9	10	11
Net Capital Costs														
Capital Project Name	€	(8.993.748,00)	€ (8.993.748,00)	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	
Total Capital Investment	**€**	**(8.993.748,00)**	**€ (8.993.748,00)**	**€ -**	**€ -**	**€ -**	**€ -**	**€ -**	**€ -**	**€ -**	**€ -**	**€ -**	**€ -**	
Operating and Maintenance Costs														
Maintenance Costs	€	(4.496.874,00)	€ -	€ (179.874,96)	€ (179.874,96)	€ (179.874,96)	€ (179.874,96)	€ (179.874,96)	€ (179.874,96)	€ (179.874,96)	€ (179.874,96)	€ (179.874,96)	€ (179.874,96)	€ (179.874,96)
Electricity Costs	€	(7.067.766,13)	€ -	€ (282.710,65)	€ (282.710,65)	€ (282.710,65)	€ (282.710,65)	€ (282.710,65)	€ (282.710,65)	€ (282.710,65)	€ (282.710,65)	€ (282.710,65)	€ (282.710,65)	€ (282.710,65)
Fuel Costs	€	(1.552.251,20)	€ -	€ (62.090,05)	€ (62.090,05)	€ (62.090,05)	€ (62.090,05)	€ (62.090,05)	€ (62.090,05)	€ (62.090,05)	€ (62.090,05)	€ (62.090,05)	€ (62.090,05)	€ (62.090,05)
Total O&M Costs excl. Escalation	**€**	**(13.116.891,32)**	**€ -**	**€ (524.675,65)**	**€ (524.675,65)**	**€ (524.675,65)**	**€ (524.675,65)**	**€ (524.675,65)**	**€ (524.675,65)**	**€ (524.675,65)**	**€ (524.675,65)**	**€ (524.675,65)**	**€ (524.675,65)**	**€ (524.675,65)**
Price Escalation Costs														
Price escalation				100%	102%	104%	106%	108%	110%	113%	115%	117%	120%	122%
Escalation of Costs	€	(3.688.627,10)	€ -	€ -	€ (10.493,51)	€ (21.196,90)	€ (32.114,35)	€ (43.250,15)	€ (54.608,66)	€ (66.194,35)	€ (78.011,75)	€ (90.065,50)	€ (102.360,32)	€ (114.901,04)
Total O&M Costs incl. Escalation	**€**	**(16.805.518,42)**	**€ -**	**€ (524.675,65)**	**€ (535.169,17)**	**€ (545.872,55)**	**€ (556.790,00)**	**€ (567.925,80)**	**€ (579.284,32)**	**€ (590.870,00)**	**€ (602.687,40)**	**€ (614.741,15)**	**€ (627.035,97)**	**€ (639.576,69)**
Revenue and Operating Benefits														
Revenue from selling electricity fixed	€	3.108.698,25	€ -	€ 124.347,93	€ 124.347,93	€ 124.347,93	€ 124.347,93	€ 124.347,93	€ 124.347,93	€ 124.347,93	€ 124.347,93	€ 124.347,93	€ 124.347,93	€ 124.347,93
Revenue from selling electricity add on				€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Benefit from CER	€	-	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Total Benefits and Revenue	**€**	**3.108.698,25**	**€ -**	**€ 124.347,93**	**€ 124.347,93**	**€ 124.347,93**	**€ 124.347,93**	**€ 124.347,93**	**€ 124.347,93**	**€ 124.347,93**	**€ 124.347,93**	**€ 124.347,93**	**€ 124.347,93**	**€ 124.347,93**
Price Escalation of Revenues														
Price change of Feed-in Tarrif fixed part				100%	102%	104%	106%	108%	110%	113%	115%	117%	120%	122%
Escalation/decrease in Revenue	€	874.203,22	€ -	€ -	€ 2.486,96	€ 5.023,66	€ 7.611,09	€ 10.250,27	€ 12.942,23	€ 15.688,04	€ 18.488,75	€ 21.345,49	€ 24.259,36	€ 27.231,50
Price change in CER				100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Escalation/decrease in Benefits	€	-	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Total R&B Costs incl. Escalation	**€**	**3.982.901,47**	**€ -**	**€ 124.347,93**	**€ 126.834,89**	**€ 129.371,59**	**€ 131.959,02**	**€ 134.598,20**	**€ 137.290,16**	**€ 140.035,97**	**€ 142.836,68**	**€ 145.693,42**	**€ 148.607,29**	**€ 151.579,43**
Total Salvage Cost	**€**	**449.687,40**	**€ -**	**€ -**	**€ -**	**€ -**	**€ -**	**€ -**	**€ -**	**€ -**	**€ -**	**€ -**	**€ -**	**€ -**
EBITDA	**€**	**(21.366.677,55)**	**€ (8.993.748,00)**	**€ (400.327,72)**	**€ (408.334,28)**	**€ (416.500,96)**	**€ (424.830,98)**	**€ (433.327,60)**	**€ (441.994,15)**	**€ (450.834,04)**	**€ (459.850,72)**	**€ (469.047,73)**	**€ (478.428,69)**	**€ (487.997,26)**
Discounted Cash Flow EBITDA	**€**	**(13.844.650,39)**	**€ (8.993.748,00)**	**€ (369.476,44)**	**€ (347.822,77)**	**€ (327.438,14)**	**€ (308.248,18)**	**€ (290.182,87)**	**€ (273.176,31)**	**€ (257.166,44)**	**€ (242.094,85)**	**€ (227.906,55)**	**€ (214.549,77)**	**€ (201.975,79)**
Debt calculation														
Principal Payments	€	(6.295.623,60)		€ (629.562,36)	€ (629.562,36)	€ (629.562,36)	€ (629.562,36)	€ (629.562,36)	€ (629.562,36)	€ (629.562,36)	€ (629.562,36)	€ (629.562,36)	€ (629.562,36)	€ -
Interests	€	(1.904.426,14)	€ -	€ (346.259,30)	€ (311.633,37)	€ (277.007,44)	€ (242.381,51)	€ (207.755,58)	€ (173.129,65)	€ (138.503,72)	€ (103.877,79)	€ (69.251,86)	€ (34.625,93)	€ -
Total Debt	**€**	**(8.200.049,74)**	**€ -**	**€ (975.821,66)**	**€ (941.195,73)**	**€ (906.569,80)**	**€ (871.943,87)**	**€ (837.317,94)**	**€ (802.692,01)**	**€ (768.066,08)**	**€ (733.440,15)**	**€ (698.814,22)**	**€ (664.188,29)**	**€ -**
Net Cash Flow After Debt	**€**	**(23.271.103,69)**	**€ (2.698.124,40)**	**€ (1.376.149,38)**	**€ (1.349.530,01)**	**€ (1.323.070,76)**	**€ (1.296.774,85)**	**€ (1.270.645,54)**	**€ (1.244.686,16)**	**€ (1.218.900,12)**	**€ (1.193.290,87)**	**€ (1.167.861,95)**	**€ (1.142.616,98)**	**€ (487.997,26)**
Fund Grant														
Grant payments	€	-	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Net Cash Flow After D & G	**€**	**(23.271.103,69)**	**€ (2.698.124,40)**	**€ (1.376.149,38)**	**€ (1.349.530,01)**	**€ (1.323.070,76)**	**€ (1.296.774,85)**	**€ (1.270.645,54)**	**€ (1.244.686,16)**	**€ (1.218.900,12)**	**€ (1.193.290,87)**	**€ (1.167.861,95)**	**€ (1.142.616,98)**	**€ (487.997,26)**
Discounted Cash Flow after D&G	**€**	**(13.115.222,97)**	**€ (2.698.124,40)**	**€ (1.270.096,34)**	**€ (1.149.541,66)**	**€ (1.040.150,84)**	**€ (940.911,80)**	**€ (850.902,58)**	**€ (769.283,41)**	**€ (695.289,56)**	**€ (628.224,68)**	**€ (567.454,79)**	**€ (512.402,83)**	**€ (201.975,79)**

Life Cycle Cost before Debt	€	13.844.650,39
Life Cycle Cost including D & G	€	13.115.222,97

12	13	14	15	16	17	18	19	20	21	22	23	24	25
€ (179.874,96)	€ (179.874,96)	€ (179.874,96)	€ (179.874,96)	€ (179.874,96)	€ (179.874,96)	€ (179.874,96)	€ (179.874,96)	€ (179.874,96)	€ (179.874,96)	€ (179.874,96)	€ (179.874,96)	€ (179.874,96)	€ (179.874,96)
€ (282.710,65)	€ (282.710,65)	€ (282.710,65)	€ (282.710,65)	€ (282.710,65)	€ (282.710,65)	€ (282.710,65)	€ (282.710,65)	€ (282.710,65)	€ (282.710,65)	€ (282.710,65)	€ (282.710,65)	€ (282.710,65)	€ (282.710,65)
€ (62.090,05)	€ (62.090,05)	€ (62.090,05)	€ (62.090,05)	€ (62.090,05)	€ (62.090,05)	€ (62.090,05)	€ (62.090,05)	€ (62.090,05)	€ (62.090,05)	€ (62.090,05)	€ (62.090,05)	€ (62.090,05)	€ (62.090,05)
€ (524.675,65)	**€ (524.675,65)**	**€ (524.675,65)**	**€ (524.675,65)**	**€ (524.675,65)**	**€ (524.675,65)**	**€ (524.675,65)**	**€ (524.675,65)**	**€ (524.675,65)**	**€ (524.675,65)**	**€ (524.675,65)**	**€ (524.675,65)**	**€ (524.675,65)**	**€ (524.675,65)**
124%	127%	129%	132%	135%	137%	140%	143%	146%	149%	152%	155%	158%	161%
€ (127.692,57)	€ (140.739,94)	€ (154.048,25)	€ (167.622,73)	€ (181.468,70)	€ (195.591,58)	€ (209.996,93)	€ (224.690,38)	€ (239.677,70)	€ (254.964,77)	€ (270.557,58)	€ (286.462,24)	€ (302.685,00)	€ (319.232,21)
€ (652.368,23)	**€ (665.415,59)**	**€ (678.723,90)**	**€ (692.298,38)**	**€ (706.144,35)**	**€ (720.267,24)**	**€ (734.672,58)**	**€ (749.366,03)**	**€ (764.353,35)**	**€ (779.640,42)**	**€ (795.233,23)**	**€ (811.137,89)**	**€ (827.360,65)**	**€ (843.907,86)**
€ 124.347,93	€ 124.347,93	€ 124.347,93	€ 124.347,93	€ 124.347,93	€ 124.347,93	€ 124.347,93	€ 124.347,93	€ 124.347,93	€ 124.347,93	€ 124.347,93	€ 124.347,93	€ 124.347,93	€ 124.347,93
€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -
€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -
€ 124.347,93	**€ 124.347,93**	**€ 124.347,93**	**€ 124.347,93**	**€ 124.347,93**	**€ 124.347,93**	**€ 124.347,93**	**€ 124.347,93**	**€ 124.347,93**	**€ 124.347,93**	**€ 124.347,93**	**€ 124.347,93**	**€ 124.347,93**	**€ 124.347,93**
124%	127%	129%	132%	135%	137%	140%	143%	146%	149%	152%	155%	158%	161%
€ 30.263,09	€ 33.355,31	€ 36.509,38	€ 39.726,52	€ 43.008,01	€ 46.355,13	€ 49.769,19	€ 53.251,53	€ 56.803,52	€ 60.426,55	€ 64.122,04	€ 67.891,44	€ 71.736,23	€ 75.657,91
100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -
€ 154.611,02	**€ 157.703,24**	**€ 160.857,31**	**€ 164.074,45**	**€ 167.355,94**	**€ 170.703,06**	**€ 174.117,12**	**€ 177.599,46**	**€ 181.151,45**	**€ 184.774,48**	**€ 188.469,97**	**€ 192.239,37**	**€ 196.084,16**	**€ 200.005,84**
€ -	**€ -**	**€ -**	**€ -**	**€ -**	**€ -**	**€ -**	**€ -**	**€ -**	**€ -**	**€ -**	**€ -**	**€ -**	**€ 449.687,40**
€ (497.757,21)	**€ (507.712,35)**	**€ (517.866,60)**	**€ (528.223,93)**	**€ (538.788,41)**	**€ (549.564,18)**	**€ (560.555,46)**	**€ (571.766,57)**	**€ (583.201,90)**	**€ (594.865,94)**	**€ (606.763,26)**	**€ (618.898,52)**	**€ (631.276,49)**	**€ (194.214,62)**
€ (190.138,72)	**€ (178.995,38)**	**€ (168.505,11)**	**€ (158.629,64)**	**€ (149.332,93)**	**€ (140.581,07)**	**€ (132.342,13)**	**€ (124.586,03)**	**€ (117.284,50)**	**€ (110.410,88)**	**€ (103.940,10)**	**€ (97.848,55)**	**€ (92.114,00)**	**€ (26.155,26)**
€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -
€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -
€ -	**€ -**	**€ -**	**€ -**	**€ -**	**€ -**	**€ -**	**€ -**	**€ -**	**€ -**	**€ -**	**€ -**	**€ -**	**€ -**
€ (497.757,21)	**€ (507.712,35)**	**€ (517.866,60)**	**€ (528.223,93)**	**€ (538.788,41)**	**€ (549.564,18)**	**€ (560.555,46)**	**€ (571.766,57)**	**€ (583.201,90)**	**€ (594.865,94)**	**€ (606.763,26)**	**€ (618.898,52)**	**€ (631.276,49)**	**€ (194.214,62)**
€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -
€ (497.757,21)	**€ (507.712,35)**	**€ (517.866,60)**	**€ (528.223,93)**	**€ (538.788,41)**	**€ (549.564,18)**	**€ (560.555,46)**	**€ (571.766,57)**	**€ (583.201,90)**	**€ (594.865,94)**	**€ (606.763,26)**	**€ (618.898,52)**	**€ (631.276,49)**	**€ (194.214,62)**
€ (190.138,72)	**€ (178.995,38)**	**€ (168.505,11)**	**€ (158.629,64)**	**€ (149.332,93)**	**€ (140.581,07)**	**€ (132.342,13)**	**€ (124.586,03)**	**€ (117.284,50)**	**€ (110.410,88)**	**€ (103.940,10)**	**€ (97.848,55)**	**€ (92.114,00)**	**€ (26.155,26)**

TECHNICAL INPUT SHEET

blue boxes with yellow text are for Data Input
text in blue are calcultated

Project Name:		**Scenario:**	
Resort Design		**Alternative 1-b (PV)**	
Location:		**Number of Guest Rooms:**	
Sharm El Sheikh		**344**	

	Energy Consumption			**Energy Produced**	
C1	Average Annual Occupancy	100%	ER1	Annual Amount of produced electricity by RET, kWh	3.963.138
C2	Average no. of occupied rooms per year	125.560	ER2	Average produced RET electricity, kWh / GN	17,06
C3	Guest to Room Ratio	1,85	ER3	Annual Amount of produced electricity by non-RET, kWh	5.467.261
C4	Average no. Of guest-nights, GN, per year	232.286	ER4	Average produced non-RET electricity, kWh / GN	23,54
C5	Average Electricity consumption / GN, kWh	34,77	ER5	Annual Amount of produced thermal energy by RET, kWh	-
C6	Annual Electricity consumption, kWh	8.077.447	ER6	Average produced RET thermal energy, kWh / GN	-
C7	Average Fuel consumption / GN, l	2,43	ER7	Annual Amount of produced thermal energy by non-RET, kWh	5.131.409
C8	Annual Fuel consumption, l	564.455	ER8	Average produced non-RET thermal energy, kWh / GN	22,09
C9	Average Thermal Energy consumption / GN, kWh	22,09		**CO2 Emissions**	
C10	Annual Thermal Energy consumption, kWh	5.131.409	CE1	CO2 conversion factor 1 MWh Grid Electricity : 1 ton Co2	0,59
	Energy Demand		CE2	CO2 conversion factor 1 litre Diesel fuel : 1 ton Co2	2,63
DD1	Surplus in supply, kWh / year	1.352.952	CE3	Annual amount of equivelant CO2 emissions	4.710
			CE4	Average amount of equivelant kg CO2 / GN	20,28

ECONOMICAL INPUT SHEET

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Project Name:			**Scenario:**		
Resort Design			**Alternative 1-b (PV)**		
Location:			**Number of Guest Rooms:**		
Sharm El Sheikh			**344**		
Financial Parameters			**Project Parameters**		
FP1	Equity ratio, ER	30%	PP1	Total Capital Investement, TCI	13.480.748 €
FP2	Fund Grant	0%	PP2	Project Life time in years	25
FP3	Debt ratio, DR	70%		**ANNUAL COSTS:**	
FP4	Cost of finance, Rd	5,50%	PP3	O & M Cost as % of TCI	2,0%
FP5	Expected return on equity, Re	15,00%	PP4	Annual O & M Cost, AOMC	269.615 €
FP6	Term of loan in years, ToL	10	PP5	Electricity purchase price per kWh	0,035 €
FP7	Term of Grant in years, ToG	0	PP6	Fuel purchase price per litre	0,11 €
FP8	Equity by Owner, E	4.044.224 €	PP7	Annual Electricity Operational Costs	282.711 €
FP9	Grant amount	- €	PP8	Annual Fuel Operational Cost	62.090 €
FP10	Debt to Bank, D	9.436.524 €		**ANNUAL REVENUES & BENEFIT**	
FP11	Weighted Average Cost of Capital, WACC	8,35%	PP9	Annual Revenue from selling electricity fixed	138.710 €
FP12	Feed-in Tarrif fixed rate per kWh	0,035 €	PP10	Annual Revenue from selling electricity add-on	- €
FP13	Feed-in Tarif added premium per kWh	- €	PP11	Annual Revenue from CER	- €
FP14	Feed-in Tarrif added premium term in years	0		**Salvage Cost**	
FP15	CER price per ton CO2	- €	PP12	Salvage Cost as % of TCI	5,0%
FP16	CER term in years	0	PP13	Total salvage Cost, TSC	674.037 €
FP17	Cost Escalation factor	2,0%			
FP18	Change in feed-in Tarrif	2,0%			
FP19	Change in CER prices	0,0%			
FP20					

REM OUTPUT SHEET

Project Name:	Scenario:
Resort Design	Alternative 1-b (PV)
Location:	**Number of Guest Rooms:**
Sharm El Sheikh	344

Economical parameters

Before Debt & Grant	per GR	Total	Including Debt & Grant	per GR	Total
LCC before Debt	55.890 €	19.226.221 €	LCC after D & G	52.712 €	18.132.881 €
NPV of Cash Flow before Debt	- 55.890 €	- 19.226.221 €	NPV of Cash Flow After D & G	- 52.712 €	- 18.132.881 €

Environmental parameters

	kg per GN	tonnes / year
Average equivelant CO2 emissions	20,28	4.710

TECHNICAL INPUT SHEET

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Project Name:			**Scenario:**		
Resort Design			**Alternative 1-c (WEC + PV)**		
Location:			**Number of Guest Rooms:**		
Sharm El Sheikh			**344**		
	Energy Consumption			**Energy Production**	
C1	Average Annual Occupancy	100%	ER1	Annual Amount of produced electricity by RET, kWh	3.745.277
C2	Average no. of occupied rooms per year	125.560	ER2	Average produced RET electricity, kWh / GN	16,12
C3	Guest to Room Ratio	1,85	ER3	Annual Amount of produced electricity by non-RET, kWh	5.163.347
C4	Average no. Of guest-nights, GN, per year	232.286	ER4	Average produced non-RET electricity, kWh / GN	22,23
C5	Average Electricity consumption / GN, kWh	34,77	ER5	Annual Amount of produced thermal energy by RET, kWh	-
C6	Annual Electricity consumption, kWh	8.077.447	ER6	Average produced RET thermal energy, kWh / GN	-
C7	Average Fuel consumption / GN, l	2,43	ER7	Annual Amount of produced thermal energy by non-RET, kWh	5.131.409
C8	Annual Fuel consumption, l	564.455	ER8	Average produced non-RET thermal energy, kWh / GN	22,09
C9	Average Thermal Energy consumption / GN, kWh	22,09		**CO2 Emissions**	
C10	Annual Thermal Energy consumption, kWh	5.131.409	CE1	CO2 conversion factor 1 MWh Grid Electricity : 1 ton Co2	0,59
	Energy Demand		CE2	CO2 conversion factor 1 litre Diesel fuel : 1 ton Co2	2,63
DD1	Surplus in supply, kWh / year	831.177	CE3	Annual amount of equivelant CO2 emissions	4.531
			CE4	Average amount of equivelant kg CO2 / GN	19,51

ECONOMICAL INPUT SHEET

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Project Name:		**Scenario:**	
Resort Design		**Alternative 1-c (WEC + PV)**	
Location:		**Number of Guest Rooms:**	
Sharm El Sheikh		**344**	

Financial Parameters			**Project Parameters**		
FP1	Equity ratio, ER	30%	PP1	Total Capital Investement, TCI	10.934.748 €
FP2	Fund Grant	0%	PP2	Project Life time in years	25
FP3	Debt ratio, DR	70%		**ANNUAL COSTS:**	
FP4	Cost of finance, Rd	5,50%	PP3	O & M Cost as % of TCI	2,0%
FP5	Expected return on equity, Re	15,00%	PP4	Annual O & M Cost, AOMC	218.695 €
FP6	Term of loan in years, ToL	10	PP5	Electricity purchase price per kWh	0,035 €
FP7	Term of Grant in years, ToG	0	PP6	Fuel purchase price per litre	0,11 €
FP8	Equity by Owner, E	3.280.424 €	PP7	Annual Electricity Operational Costs	282.711 €
FP9	Grant amount	- €	PP8	Annual Fuel Operational Cost	62.090 €
FP10	Debt to Bank, D	7.654.324 €		**ANNUAL REVENUES & BENEFIT**	
FP11	Weighted Average Cost of Capital, WACC	8,35%	PP9	Annual Revenue from selling electricity fixed	131.085 €
FP12	Feed-in Tarrif fixed rate per kWh	0,035 €	PP10	Annual Revenue from selling electricity add-on	- €
FP13	Feed-in Tarif added premium per kWh	- €	PP11	Annual Revenue from CER	- €
FP14	Feed-in Tarrif added premium term in years	0		**Salvage Cost**	
FP15	CER price per ton CO2	- €	PP12	Salvage Cost as % of TCI	5,0%
FP16	CER term in years	0	PP13	Total salvage Cost, TSC	546.737 €
FP17	Cost Escalation factor	2,0%			
FP18	Change in feed-in Tarrif	2,0%			
FP19	Change in CER prices	0,0%			
FP20					

REM OUTPUT SHEET

Project Name:	Scenario:
Resort Design	Alternative 1-c (WEC + PV)
Location:	Number of Guest Rooms:
Sharm El Sheikh	344

Economical parameters

Before Debt & Grant	per GR	Total	Including Debt & Grant	per GR	Total
LCC before Debt	46.995 €	16.166.197 €	LCC after D & G	44.417 €	15.279.347 €
NPV of Cash Flow before Debt	- 46.995 €	- 16.166.197 €	NPV of Cash Flow After D & G	- 44.417 €	- 15.279.347 €

Environmental parameters

	kg per GN	tonnes / year
Average equivelant CO2 emissions	19,51	4.531

Alternative 1-C (WECS + PV)

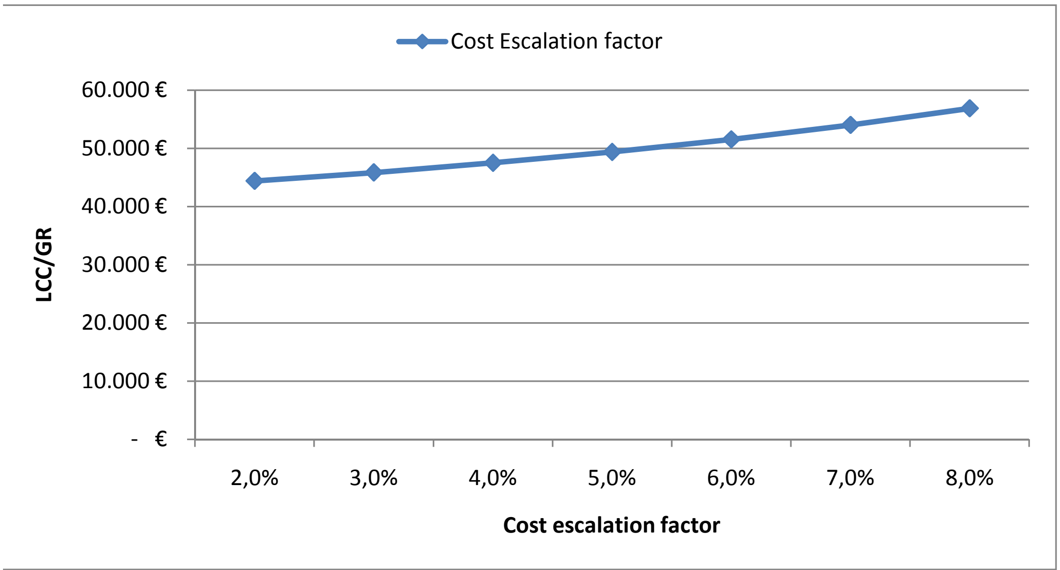
Sensibility's analysis WACC v. LCC/GR

Equity ratio, ER	Cost of finance, Rd	Weighted Average Cost of Capital, WACC	LCC after D & G / per GR
30%	5,00%	8,00%	44.741 €
30%	6,00%	8,70%	44.112 €
30%	7,00%	9,40%	43.558 €
30%	8,00%	10,10%	43.069 €
40%	5,00%	9,00%	43.107 €
40%	6,00%	9,60%	42.742 €
40%	7,00%	10,20%	42.420 €
40%	8,00%	10,80%	42.136 €
50%	5,00%	10,00%	41.910 €
50%	6,00%	10,50%	41.731 €
50%	7,00%	11,00%	41.574 €
50%	8,00%	11,50%	41.439 €
60%	5,00%	11,00%	41.099 €
60%	6,00%	11,40%	41.042 €
60%	7,00%	11,80%	40.996 €
60%	8,00%	12,20%	40.960 €
70%	5,00%	12,00%	40.631 €
70%	6,00%	12,30%	40.644 €
70%	7,00%	12,60%	40.661 €
70%	8,00%	12,90%	40.683 €
80%	5,00%	13,00%	40.467 €
80%	6,00%	13,20%	40.508 €
80%	7,00%	13,40%	40.550 €
80%	8,00%	13,60%	40.593 €
90%	5,00%	14,00%	40.575 €
90%	6,00%	14,10%	40.609 €
90%	7,00%	14,20%	40.644 €
90%	8,00%	14,30%	40.679 €
100%	5,00%	15,00%	40.926 €
100%	6,00%	15,00%	40.926 €
100%	7,00%	15,00%	40.926 €
100%	8,00%	15,00%	40.926 €

Alternative 1-C (WECS + PV)

Sensibility's analysis

Cost Escalation factor	Change in feed-in Tarrif	LCC after D & G / per GR
2,0%	2,0%	44.417 €
3,0%	3,0%	45.865 €
4,0%	4,0%	47.517 €
5,0%	5,0%	49.406 €
6,0%	6,0%	51.568 €
7,0%	7,0%	54.049 €
8,0%	8,0%	56.901 €



Alternative 1-C (WECS + PV)

Sensibility's analysis energy price v. LCC

Feed-in Tarrif fixed rate per kWh	Electricity purchase price per kWh	Fuel purchase price per litre	LCC after D & G / per GR
0,030 €	0,030 €	0,10 €	43.443 €
0,030 €	0,030 €	0,30 €	47.469 €
0,030 €	0,030 €	0,50 €	51.495 €
0,030 €	0,030 €	0,70 €	55.521 €
0,030 €	0,030 €	0,90 €	59.548 €
0,080 €	0,080 €	0,10 €	51.168 €
0,080 €	0,080 €	0,30 €	55.194 €
0,080 €	0,080 €	0,50 €	59.221 €
0,080 €	0,080 €	0,70 €	63.247 €
0,080 €	0,080 €	0,90 €	67.273 €
0,130 €	0,130 €	0,10 €	58.893 €
0,130 €	0,130 €	0,30 €	62.920 €
0,130 €	0,130 €	0,50 €	66.946 €
0,130 €	0,130 €	0,70 €	70.972 €
0,130 €	0,130 €	0,90 €	74.998 €
0,180 €	0,180 €	0,10 €	66.619 €
0,180 €	0,180 €	0,30 €	70.645 €
0,180 €	0,180 €	0,50 €	74.671 €
0,180 €	0,180 €	0,70 €	78.697 €
0,180 €	0,180 €	0,90 €	82.723 €
0,230 €	0,230 €	0,10 €	74.344 €
0,230 €	0,230 €	0,30 €	78.370 €
0,230 €	0,230 €	0,50 €	82.396 €
0,230 €	0,230 €	0,70 €	86.422 €
0,230 €	0,230 €	0,90 €	90.449 €

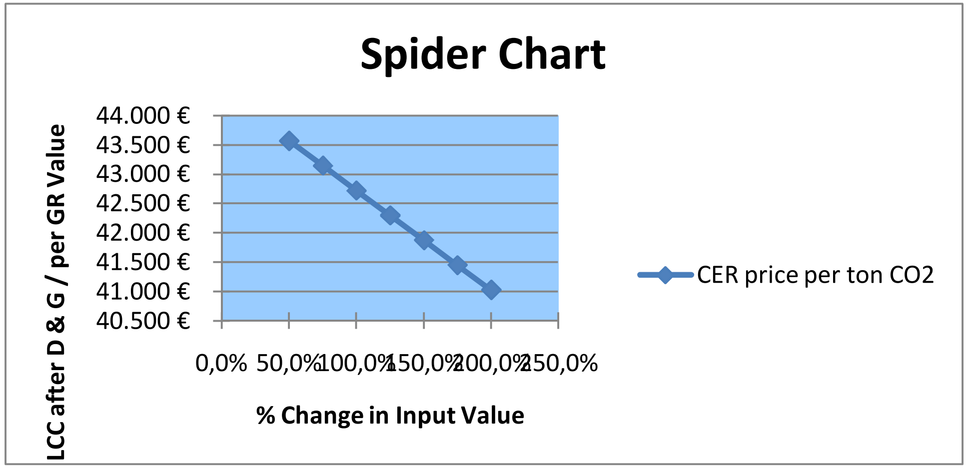
Alternative 1-C (WECS + PV)

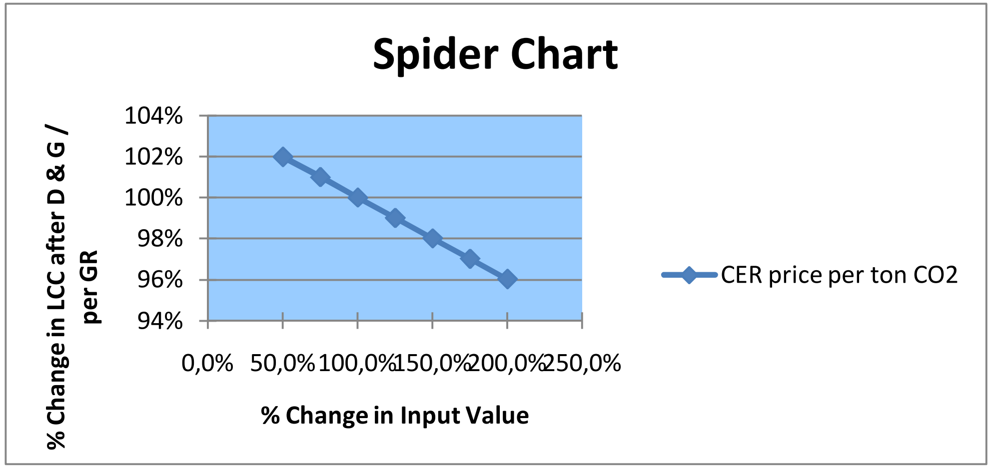
Sensibility's analysis for "LCC after D & G / per GR"

	Input Variables Values						
	50,0%	75,0%	100,0%	125,0%	150,0%	175,0%	200,0%
CER price per ton CC	8,00 €	12,00 €	16,00 €	20,00 €	24,00 €	28,00 €	32,00 €

	Output Variable Values "LCC after D & G / per GR"						
	50,0%	75,0%	100,0%	125,0%	150,0%	175,0%	200,0%
CER price per ton CC	43.568 €	43.144 €	42.720 €	42.296 €	41.872 €	41.448 €	41.023 €

	Output Variable Percent Variation "LCC after D & G / per GR"						
	50,0%	75,0%	100,0%	125,0%	150,0%	175,0%	200,0%
CER price per ton CC	101,99%	100,99%	100,00%	99,01%	98,01%	97,02%	96,03%





TECHNICAL INPUT SHEET

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Project Name:			**Scenario:**		
Resort Design			**Alternative 2 (WECS, PV, SC)**		
Location:			**Number of Guest Rooms:**		
Sharm El Sheikh			**344**		
	Energy Consumption			**Energy Production**	
C1	Average Annual Occupancy	100%	ER1	Annual Amount of produced electricity by RET, kWh	3.745.277
C2	Average no. of occupied rooms per year	125.560	ER2	Average produced RET electricity, kWh / GN	16,12
C3	Guest to Room Ratio	1,85	ER3	Annual Amount of produced electricity by non-RET, kWh	5.163.347
C4	Average no. Of guest-nights, GN, per year	232.286	ER4	Average produced non-RET electricity, kWh / GN	22,23
C5	Average Electricity consumption / GN, kWh	34,77	ER5	Annual Amount of produced thermal energy by RET, kWh	460.000
C6	Annual Electricity consumption, kWh	8.077.447	ER6	Average produced RET thermal energy, kWh / GN	1,98
C7	Average Fuel consumption / GN, l	0,62	ER7	Annual Amount of produced thermal energy by non-RET, kWh	1.314.000
C8	Annual Fuel consumption, l	144.540	ER8	Average produced non-RET thermal energy, kWh / GN	5,66
C9	Average Thermal Energy consumption / GN, kWh	7,64		**CO2 Emissions**	
C10	Annual Thermal Energy consumption, kWh	1.774.000	CE1	CO2 conversion factor 1 MWh Grid Electricity : 1 ton Co2	0,59
	Energy Demand		CE2	CO2 conversion factor 1 litre Diesel fuel : 1 ton Co2	2,63
DD1	Surplus in supply, kWh / year	831.177	CE3	Annual amount of equivelant CO2 emissions	3.427
			CE4	Average amount of equivelant kg CO2 / GN	14,75

ECONOMICAL INPUT SHEET

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Project Name:			**Scenario:**		
	Resort Design		Alternative 2 (WECS, PV, SC)		
Location:			**Number of Guest Rooms:**		
	Sharm El Sheikh			344	
Financial Parameters			**Projec**	Energy Production	
FP1	Equity ratio, ER	30%	PP1	Total Capital Investement, TCI	11.047.708,00 €
FP2	Fund Grant	0%	PP2	Project Life time in years	25
FP3	Debt ratio, DR	70%		**ANNUAL COSTS:**	
FP4	Cost of finance, Rd	5,50%	PP3	M & R Cost as % of TCI	2,0%
FP5	Expected return on equity, Re	15,00%	PP4	Annual M & R Cost, AMRC	220.954 €
FP6	Term of loan in years, ToL	10	PP5	Electricity purchase price per kWh	0,035 €
FP7	Term of Grant in years, ToG	0	PP6	Fuel purchase price per litre	0,11 €
FP8	Equity by Owner, E	3.314.312 €	PP7	Annual Electricity Operational Costs	282.711 €
FP9	Grant amount	- €	PP8	Annual Fuel Operational Cost	15.899 €
FP10	Debt to Bank, D	7.733.396 €		**ANNUAL REVENUES & BENEFIT**	
FP11	Weighted Average Cost of Capital, WACC	8,35%	PP9	Annual Revenue from selling electricity fixed	131.085 €
FP12	Feed-in Tarrif fixed rate per kWh	0,035 €	PP10	Annual Revenue from selling electricity add-on	- €
FP13	Feed-in Tarif added premium per kWh	- €	PP11	Annual Revenue from CER	- €
FP14	Feed-in Tarrif added premium term in years	0		**Salvage Cost**	
FP15	CER price per ton CO2	- €	PP12	Salvage Cost as % of TCI	5,0%
FP16	CER term in years	20	PP13	Total salvage Cost, TSC	552.385 €
FP17	Cost Escalation factor	2,0%		**Renewable factor**	
FP18	Change in feed-in Tarrif	2,0%	PP14	Power	36,08%
FP19	Change in CER prices	0,0%		Thermal	25,93%
FP20				Overall	35,36%

REM OUTPUT SHEET

Project Name:	Scenario:
Resort Design	Alternative 2 (WECS, PV, SC)
Location:	Number of Guest Rooms:
Sharm El Sheikh	344

Economical parameters

Before Debt & Grant	per GR	Total	Energy Production	per GR	Total
LCC before Debt	45.754 €	15.739.419 €	LCC after D & G	43.149 €	14.843.407 €
NPV of Cash Flow before Debt	- 45.754 €	- 15.739.419 €	NPV of Cash Flow After D & G	- 43.149 €	- 14.843.407 €

Environmental parameters

	kg per GN	tonnes / year
Average equivelant CO2 emissions	14,75	3.426,51

Alternative 2 (WECS, PV, SC)

Sensibility's analysis

Equity ratio, ER	Cost of finance, Rd	Weighted Average Cost of Capital, WACC	LCC after D & G / per GR
30%	5,00%	8,00%	43.420 €
30%	6,00%	8,70%	42.896 €
30%	7,00%	9,40%	42.437 €
30%	8,00%	10,10%	42.034 €
40%	5,00%	9,00%	Energy Production
40%	6,00%	9,60%	41.639 €
40%	7,00%	10,20%	41.391 €
40%	8,00%	10,80%	41.175 €
50%	5,00%	10,00%	40.851 €
50%	6,00%	10,50%	40.730 €
50%	7,00%	11,00%	40.629 €
50%	8,00%	11,50%	40.546 €
60%	5,00%	11,00%	40.149 €
60%	6,00%	11,40%	40.134 €
60%	7,00%	11,80%	40.129 €
60%	8,00%	12,20%	40.131 €
70%	5,00%	12,00%	39.779 €
70%	6,00%	12,30%	39.821 €
70%	7,00%	12,60%	39.866 €
70%	8,00%	12,90%	39.914 €
80%	5,00%	13,00%	39.705 €
80%	6,00%	13,20%	39.763 €
80%	7,00%	13,40%	39.822 €
80%	8,00%	13,60%	39.882 €
90%	5,00%	14,00%	39.894 €
90%	6,00%	14,10%	39.937 €
90%	7,00%	14,20%	39.979 €
90%	8,00%	14,30%	40.021 €
100%	5,00%	15,00%	40.321 €
100%	6,00%	15,00%	40.321 €
100%	7,00%	15,00%	40.321 €
100%	8,00%	15,00%	40.321 €

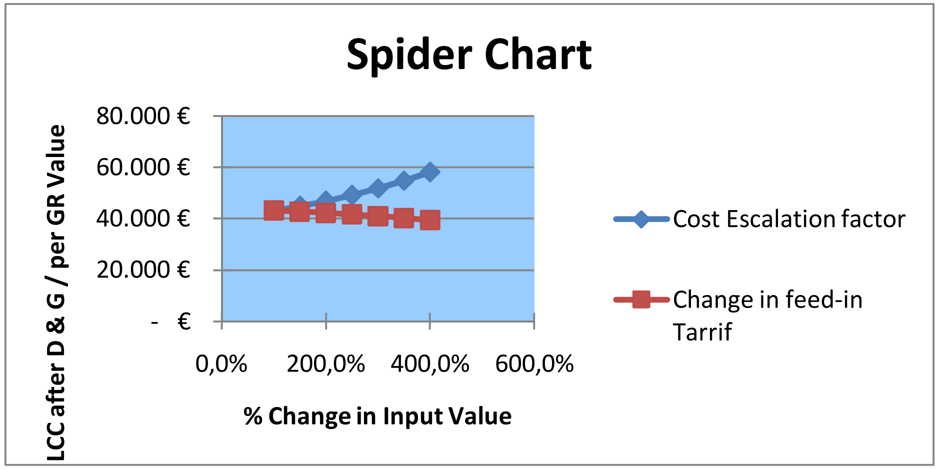
Alternative 2 (WECS, PV, SC)

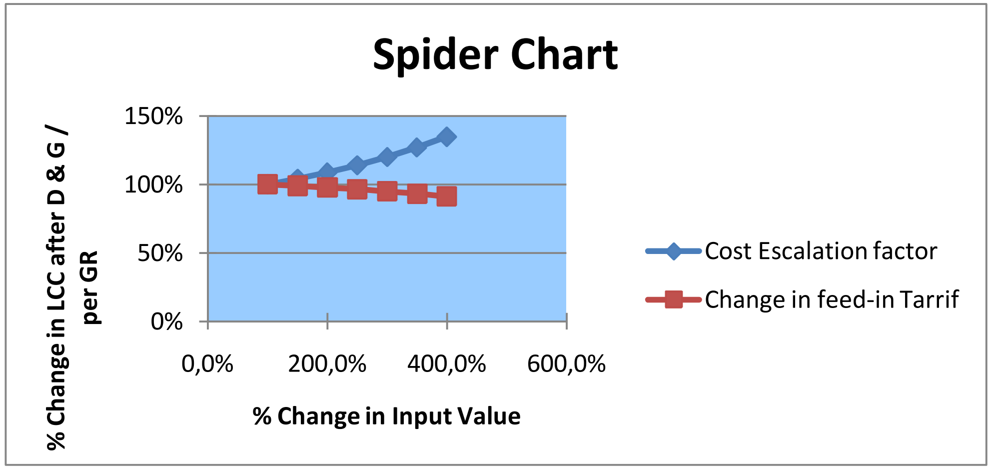
Sensibility's analysis for "LCC after D & G / per GR"

	Input Variables Values						
	100,0%	150,0%	Alternative 2	250,0%	300,0%	100%	400,0%
Cost Escalation factor	2,0%	3,0%	4,0%	5,0%	6,0%	7,0%	8,0%
Change in feed-in Tar	2,0%	3,0%	4,0%	5,0%	6,0%	7,0%	8,0%

	Output Variable Values "LCC after Energy Production						
	100,0%	150,0%	200,0%	250,0%	300,0%	350,0%	400,0%
Cost Escalation factor	43.149 €	44.890 €	46.875 €	49.144 €	51.742 €	54.723 €	58.151 €
Change in feed-in Tar	43.149 €	42.710 €	42.209 €	41.637 €	40.982 €	40.229 €	39.365 €

	Output Variable Percent Variation "LCC after D & G / per GR"						
	100,0%	150,0%	200,0%	250,0%	300,0%	350,0%	400,0%
Cost Escalation factor	100,00%	104,03%	108,63%	113,89%	119,91%	126,82%	134,77%
Change in feed-in Tar	100,00%	98,98%	97,82%	96,50%	94,98%	93,23%	91,23%





Alternative 2 (WECS, PV, SC)

Sensibility's analysis energy prices v. LCC

Feed-in Tarrif fixed rate per kWh	Electricity purchase price per kWh	Fuel purchase price per litre	LCC after D & G / per GR
0,030 €	0,030 €	0,10 €	42.325 €
0,030 €	0,030 €	0,30 €	43.356 €
0,030 €	0,030 €	0,50 €	44.387 €
0,030 €	0,030 €	0,70 €	45.418 €
0,030 €	0,030 €	0,90 €	46.449 €
0,080 €	0,080 €	0,10 €	50.051 €
0,080 €	0,080 €	0,30 €	51.082 €
0,080 €	0,080 €	0,50 €	52.113 €
0,080 €	0,080 €	0,70 €	53.144 €
0,080 €	0,080 €	0,90 €	54.175 €
0,130 €	0,130 €	0,10 €	57.776 €
0,130 €	0,130 €	0,30 €	58.807 €
0,130 €	0,130 €	0,50 €	59.838 €
0,130 €	0,130 €	0,70 €	60.869 €
0,130 €	0,130 €	0,90 €	61.900 €
0,180 €	0,180 €	0,10 €	65.501 €
0,180 €	0,180 €	0,30 €	66.532 €
0,180 €	0,180 €	0,50 €	67.563 €
0,180 €	0,180 €	0,70 €	68.594 €
0,180 €	0,180 €	0,90 €	69.625 €
0,230 €	0,230 €	0,10 €	73.226 €
0,230 €	0,230 €	0,30 €	74.257 €
0,230 €	0,230 €	0,50 €	75.288 €
0,230 €	0,230 €	0,70 €	76.319 €
0,230 €	0,230 €	0,90 €	77.350 €

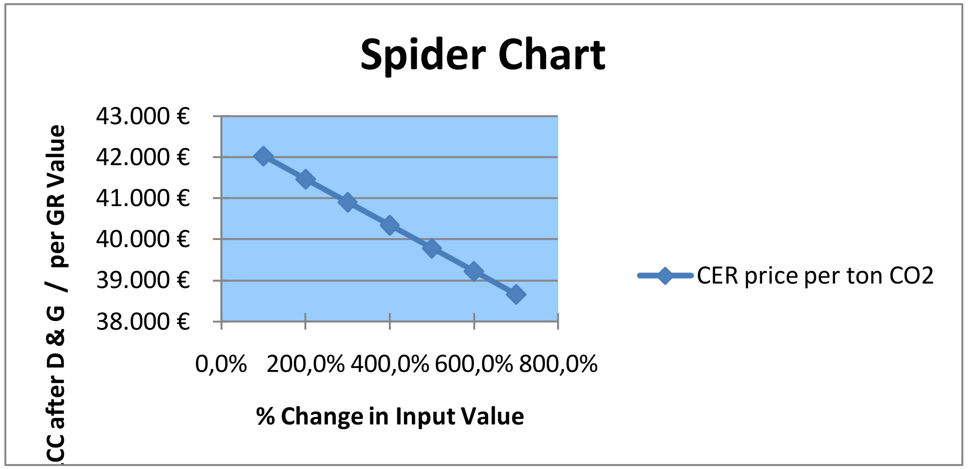
Alternative 2 (WECS, PV, SC)

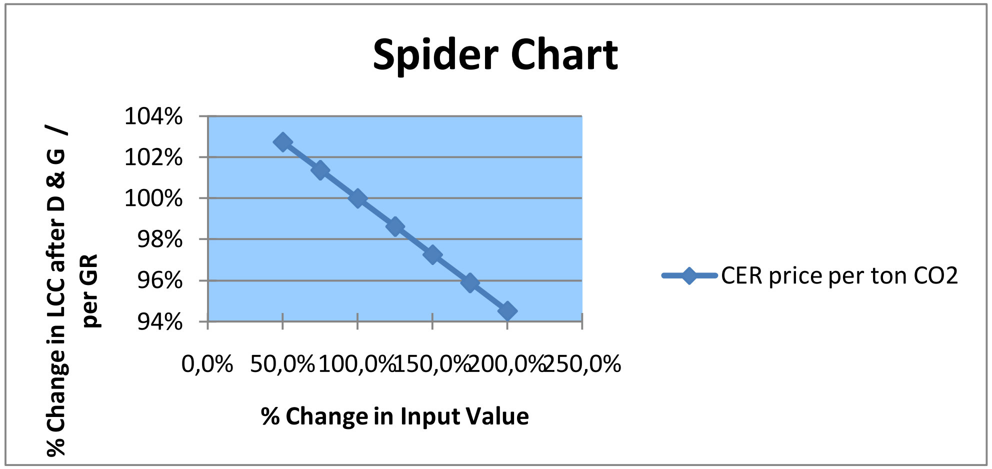
Sensibility's analysis for "LCC after D & G / per GR"

	Input Variables Values						
	50,0%	75,0%	Alternative 2	125,0%	150,0%	100%	200,0%
CER price per ton CO	8,00 €	12,00 €	16,00 €	20,00 €	24,00 €	28,00 €	32,00 €

	Output Variable Values "LCC after D & G / per GR"						
	50,0%	75,0%	100,0%	Energy Proc	150,0%	175,0%	200,0%
CER price per ton CO	42.029 €	41.468 €	40.908 €	40.348 €	39.787 €	39.227 €	38.667 €

	Output Variable Percent Variation "LCC after D & G / per GR"						
	50,0%	75,0%	100,0%	125,0%	150,0%	175,0%	200,0%
CER price per ton CO	102,74%	101,37%	100,00%	98,63%	97,26%	95,89%	94,52%





TECHNICAL INPUT SHEET

blue boxes with yellow text are for Data Input
text in blue are calcultated

Project Name:			**Scenario:**		
Resort Design			**Alternative 3 (CSP)**		
Location:			**Number of Guest Rooms:**		
Sharm El Sheikh			**344**		
	Energy Consumption			**Energy Production**	
C1	Average Annual Occupancy	100%	ER1	Annual Amount of produced electricity by RET, kWh	4.523.500
C2	Average no. of occupied rooms per year	125.560	ER2	Average produced RET electricity, kWh / GN	19,47
C3	Guest to Room Ratio	1,85	ER3	Annual Amount of produced electricity by non-RET, kWh	2.190.000
C4	Average no. Of guest-nights, GN, per year	232.286	ER4	Average produced non-RET electricity, kWh / GN	9,43
C5	Average Electricity consumption / GN, kWh	25,93	ER5	Annual Amount of produced thermal energy by RET, kWh	15.300.800
C6	Annual Electricity consumption, kWh	6.022.500	ER6	Average produced RET thermal energy, kWh / GN	65,87
C7	Average Fuel consumption / GN, l	0,47	ER7	Annual Amount of produced thermal energy by non-RET, kWh	985.227
C8	Annual Fuel consumption, l	108.375	ER8	Average produced non-RET thermal energy, kWh / GN	4,24
C9	Average Thermal Energy consumption / GN, kWh	31,23		**CO2 Emissions**	
C10	Annual Thermal Energy consumption, kWh	7.253.363	CE1	CO2 conversion factor 1 MWh Grid Electricity : 1 ton Co2	0,59
	Energy Demand		CE2	CO2 conversion factor 1 litre Diesel fuel : 1 ton Co2	2,63
DD1	Surplus in supply, kWh / year	691.000	CE3	Annual amount of equivelant CO2 emissions	1.577
			CE4	Average amount of equivelant kg CO2 / GN	6,79

ECONOMICAL INPUT SHEET

blue boxes with yellow text are for Data Input
text in blue are calcultated

Project Name:			Scenario:		
Resort Design			Alternative 3 (CSP)		
Location:			Number of Guest Rooms:		
Sharm El Sheikh			344		
Financial Parameters			**Projec**	Energy Production	
FP1	Equity ratio, ER	30%	PP1	Total Capital Investement, TCI	12.563.237,00 €
FP2	Fund Grant	0%	PP2	Project Life time in years	25
FP3	Debt ratio, DR	70%		**ANNUAL COSTS:**	
FP4	Cost of finance, Rd	5,50%	PP3	O & M Cost as % of TCI	2,0%
FP5	Expected return on equity, Re	15,00%	PP4	Annual O & M Cost, AOMC	251.265 €
FP6	Term of loan in years, ToL	10	PP5	Electricity purchase price per kWh	0,035 €
FP7	Term of Grant in years, ToG	0	PP6	Fuel purchase price per litre	0,11 €
FP8	Equity by Owner, E	3.768.971 €	PP7	Annual Electricity Operational Costs	210.788 €
FP9	Grant amount	- €	PP8	**Annual Fuel Operational Cost**	**11.921**
FP10	Debt to Bank, D	8.794.266 €		**ANNUAL REVENUES & BENEFIT**	
FP11	Weighted Average Cost of Capital, WACC	8,35%	PP9	Annual Revenue from selling electricity fixed	158.323 €
FP12	Feed-in Tarrif fixed rate per kWh	0,035 €	PP10	Annual Revenue from selling electricity add-on	- €
FP13	Feed-in Tarif added premium per kWh	- €	PP11	Annual Revenue from CER	- €
FP14	Feed-in Tarrif added premium term in years	0		**Salvage Cost**	
FP15	CER price per ton CO2	- €	PP12	Salvage Cost as % of TCI	5,0%
FP16	CER term in years	20	PP13	Total salvage Cost, TSC	628.162 €
FP17	Cost Escalation factor	2,0%		**Renewable factor**	
FP18	Change in feed-in Tarrif	2,0%	PP14	Power	63,64%
FP19	Change in CER prices	0,0%		Thermal	86,42%
FP20				Overall	**70,33%**

REM OUTPUT SHEET

Project Name:			Scenario:		
Resort Design			Alternative 3 (CSP)		
Location:			Number of Guest Rooms:		
Sharm El Sheikh			344		

Economical parameters

Before Debt & Grant	per GR	Total	Energy Production	per GR	Total
LCC before Debt	47.533 €	16.351.239 €	LCC after D & G	44.571 €	15.332.312 €
NPV of Cash Flow before Debt	- 47.533 €	- 16.351.239 €	NPV of Cash Flow After D & G	- 44.571 €	- 15.332.312 €

Environmental parameters

	kg per GN	tonnes / year
Average equivelant CO2 emissions	6,79	1.577

Alternative 3 (CSP)

Sensibility's analysis WACC v. LCC

Equity ratio, ER	Cost of finance, Rd	Weighted Average Cost of Capital, WACC	LCC after D & G / per GR
30%	5,00%	8,00%	44.730 €
30%	6,00%	8,70%	44.424 €
30%	7,00%	9,40%	44.164 €
30%	8,00%	10,10%	43.944 €
40%	5,00%	9,00%	43.435 €
40%	6,00%	9,60%	43.327 €
40%	7,00%	10,20%	43.244 €
40%	8,00%	10,80%	43.183 €
50%	5,00%	10,00%	42.565 €
50%	6,00%	10,50%	42.588 €
50%	7,00%	11,00%	42.621 €
50%	8,00%	11,50%	42.665 €
60%	5,00%	11,00%	42.075 €
60%	6,00%	11,40%	42.170 €
60%	7,00%	11,80%	42.270 €
60%	8,00%	12,20%	42.373 €
70%	3,50%	12,00%	41.924 €
70%	6,00%	12,30%	42.046 €
70%	7,00%	12,60%	42.168 €
70%	0,00%	12,90%	42.292 €
80%	5,00%	13,00%	42.076 €
80%	6,00%	13,20%	42.186 €
80%	7,00%	13,40%	42.296 €
80%	8,00%	13,60%	42.406 €
90%	5,00%	14,00%	42.501 €
90%	6,00%	14,10%	42.569 €
90%	7,00%	14,20%	42.637 €
90%	8,00%	14,30%	42.704 €
100%	5,00%	15,00%	43.172 €
100%	6,00%	15,00%	43.172 €
100%	7,00%	15,00%	43.172 €
100%	8,00%	15,00%	43.172 €

Alternative 3 (CSP)

Sensibility's analysis energy prices v. LCC

Feed-in Tarrif fixed rate per kWh	Electricity purchase price per kWh	Fuel purchase price per litre	LCC after D & G / per GR
0,030 €	0,030 €	0,10 €	44.265 €
0,030 €	0,030 €	0,30 €	45.038 €
0,030 €	0,030 €	0,50 €	45.811 €
0,030 €	0,030 €	0,70 €	46.584 €
0,030 €	0,030 €	0,90 €	47.357 €
0,080 €	0,080 €	0,10 €	46.938 €
0,080 €	0,080 €	0,30 €	47.711 €
0,080 €	0,080 €	0,50 €	48.484 €
0,080 €	0,080 €	0,70 €	49.257 €
0,080 €	0,080 €	0,90 €	50.030 €
0,130 €	0,130 €	0,10 €	49.611 €
0,130 €	0,130 €	0,30 €	50.384 €
0,130 €	0,130 €	0,50 €	51.157 €
0,130 €	0,130 €	0,70 €	51.930 €
0,130 €	0,130 €	0,90 €	52.703 €
0,180 €	0,180 €	0,10 €	52.284 €
0,180 €	0,035 €	0,30 €	53.057 €
0,180 €	0,180 €	0,50 €	53.830 €
0,180 €	0,180 €	0,70 €	54.603 €
0,180 €	- €	0,90 €	55.376 €
0,230 €	0,230 €	0,10 €	54.957 €
0,230 €	0,230 €	0,30 €	55.730 €
0,230 €	0,230 €	0,50 €	56.503 €
0,230 €	0,230 €	0,70 €	57.276 €
0,230 €	0,230 €	0,90 €	58.049 €
0,280 €	0,280 €	0,10 €	57.630 €
0,280 €	0,280 €	0,30 €	58.403 €
0,280 €	0,280 €	0,50 €	59.176 €
0,280 €	0,280 €	0,70 €	59.949 €
0,280 €	0,280 €	0,90 €	60.722 €

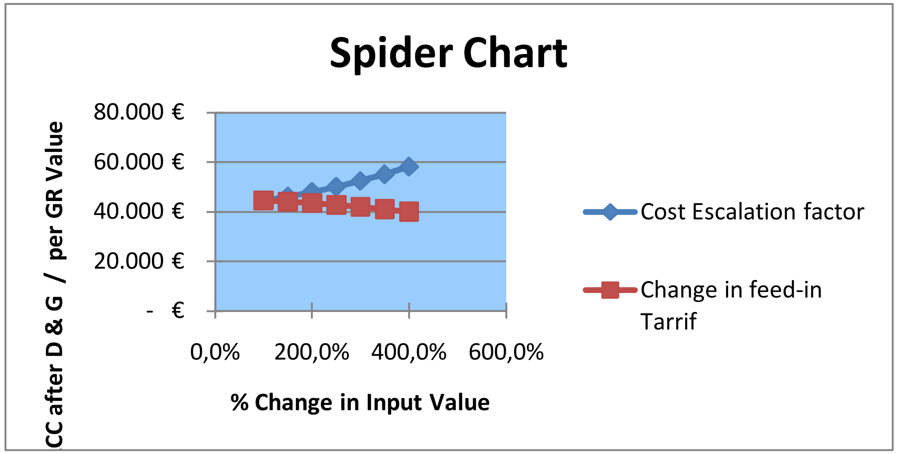
Alternative 3 (CSP)

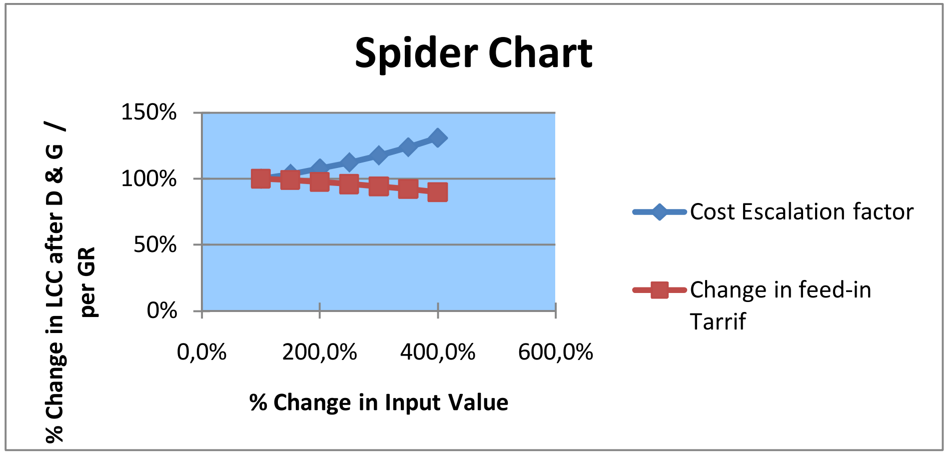
Sensibility's analysis for "LCC after D & G / per GR"

	Input Variables Values						
	100,0%	150,0%	Alternative :	250,0%	300,0%	100%	400,0%
Cost Escalation factor	2,0%	3,0%	4,0%	5,0%	6,0%	7,0%	8,0%
Change in feed-in Tar	2,0%	3,0%	4,0%	5,0%	6,0%	7,0%	8,0%
						-100%	

	Output Variable Values "LCC after Energy Production						
	100,0%	150,0%	200,0%	250,0%	300,0%	350,0%	400,0%
Cost Escalation factor	44.571 €	46.159 €	47.969 €	50.039 €	52.409 €	55.129 €	58.255 €
Change in feed-in Tar	44.571 €	44.040 €	43.435 €	42.744 €	41.952 €	41.044 €	40.000 €

	Output Variable Percent Variation "LCC after D & G / per GR"						
	100,0%	150,0%	200,0%	250,0%	300,0%	350,0%	400,0%
Cost Escalation factor	100,00%	103,56%	107,63%	112,27%	117,59%	123,69%	130,70%
Change in feed-in Tar	100,00%	98,81%	97,45%	95,90%	94,13%	92,09%	89,74%





Alternative 3 (CSP)

Sensibility's analysis for "LCC after D & G / per GR"

	Input Variables Values						
	50,0%	75,0%	Alternative :	125,0%	150,0%	100%	200,0%
CER price per ton CC	8,00 €	12,00 €	16,00 €	20,00 €	24,00 €	28,00 €	32,00 €

	Output Variable Values "LCC after D & G / per GR"					-100%	
	50,0%	75,0%	100,0%	Energy Proc	150,0%	175,0%	200,0%
CER price per ton CC	43.004 €	42.221 €	41.438 €	40.655 €	39.871 €	39.088 €	38.305 €

	Output Variable Percent Variation "LCC after D & G / per GR"						
	50,0%	75,0%	100,0%	125,0%	150,0%	175,0%	200,0%
CER price per ton CC	103,78%	101,89%	100,00%	98,11%	96,22%	94,33%	92,44%